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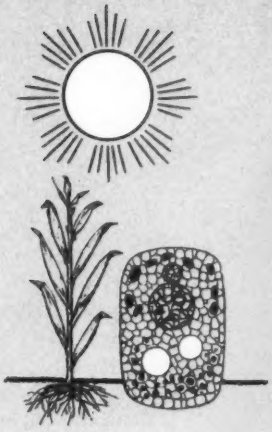
THE ENVIRONMENT AND AGRICULTURE
Issues and Answers Page 1



AGRICULTURAL SCIENCE REVIEW

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Quality of Life: Earth Dependent

A Guest Editorial by Dr. René Dubos

During my school days in France, at the beginning of the century, I learned that the development or introduction of new varieties of plants, breeds of animals, and methods of cultivation had begun to transform agriculture and to enrich Europe long before modern times. The application of scientific research to farm problems is thus very old. But it is also certain, on the other hand, that the creation of the land grant colleges and agricultural experiment stations in the United States represented a really new departure for the late 19th century, because it constituted the first systematic attempt to convert farming from a practice to a technological discipline.

The productivity and efficiency of modern agriculture is not the only evidence for the success of this new approach. Increasingly all over the world, much of agricultural research is now conducted outside universities by private enterprises such as the fertilizer and pesticide industries, the producers of seeds and feeds, the farm implement makers.

In contrast, academic scientists are becoming more and more oriented toward theoretical problems which, even when they are directly relevant to agriculture, are not likely to exert a significant effect on its course. Yet, there are many reasons to believe that the directions of the agricultural enterprise will soon have to be altered, because some of its present practices are incompatible with ecological constraints.

During the 19th and 20th centuries, the success of Western civilization was measured almost exclusively in terms of quantitative production of food and manufactured goods rather than of quality of life. This attitude was justified until a few decades ago, because, on balance, most increases in production resulted in healthier, longer, and richer life. However, the mounting roster of environmental problems, which have resulted from technical advances, strongly suggests that this phase of Western civilization will soon come to an end. Modern societies can survive only if they make *quality of*

(*Continued on page 23*)

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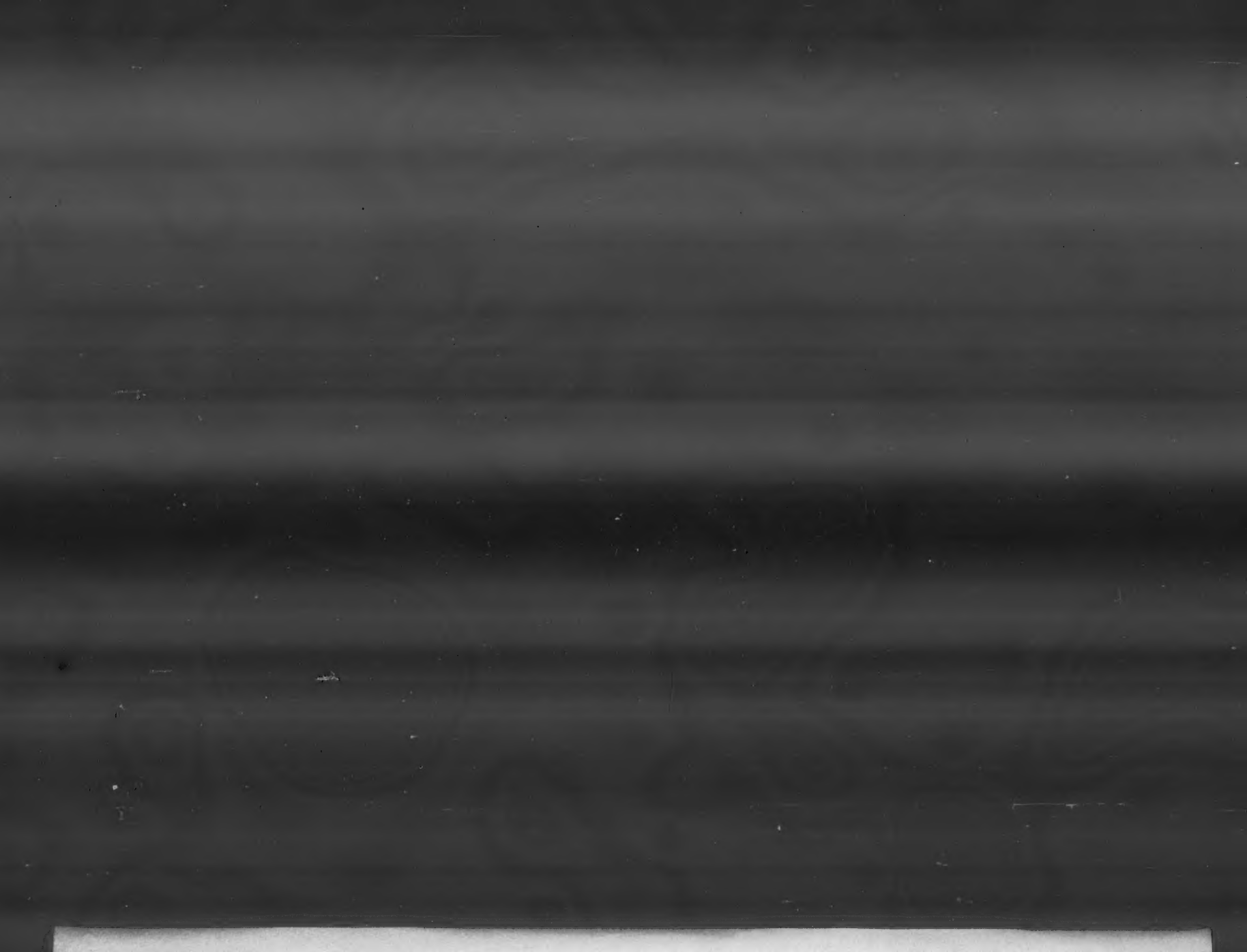

THE ENVIRONMENT AND AGRICULTURE

Issues and Answers

T. C. BYERLY

MUCH has already been written about our environmental problems. In the months and years ahead, we can reasonably expect the commentary on this subject—both oral and written—to continue proliferating.

If some of this commentary may be termed "fancy rhetoric," it is only because man finds himself in a bewildering state of confusion as to what needs to be done, what can be done, and how to do it. Hugh Bennett used rhetoric to start a crusade. And because of it, we learned how to better manage our soil resources.

Whether we start with rhetoric or not, the issues involved must be properly identified—and then resolved through whatever mode of action suits best. In this paper I have undertaken to answer six questions that either directly or indirectly concern agriculture's role in environmental quality.

What is the environment?

Simply, it is the aggregate of surrounding things, conditions, and influences. But surrounding what? Surrounding me; surrounding you; surrounding us. Our primary concern is with the environment of which we are a part, of that of which our progeny for generations to come will be a part.

President Nixon, in his State of the Union Message, phrased it this way: "The truly significant environment for each of us is that in which we spend eighty percent of our time—that is, our homes, our places of work and the streets over which we pass."

But while each of our micro-environments may add up to the global environment, it is not likely that we can understand the global environment by limiting our studies to the niches in which we live.

The "space ship earth" analogy has some conceptual significance. The National Research Council's Geophysical Research Board, in a report of a summer study of the role of ground-based research, describes the earth as "a giant spin-stabilized spacecraft" (*6*).[1]

What are the major factors and interactions determining the quality of the environment?

Whether urban or rural, global, terrestrial, aquatic, macro, meso, or micro, environments in which people live do have some common parameters. Somehow we must use measurements of these parameters in developing an index of quality.

A recent report (*2*) by the Environmental Studies Board of the National Academy of Sciences—National Academy of Engineering suggests that we

This article was adapted from a talk given by the author at the 1970 National Agricultural Outlook Conference, Feb. 17, 1970, Washington, D.C.

[1] Italic numbers in parentheses refer to Literature Cited, p. 8.

must monitor and take account of changes in at least the following factors:

- Physical and chemical properties of land, air, and water.
- Distribution of plants and animals in land, air, and water.
- Land use, including diversity of purpose.
- Construction.
- Noise.
- Epidemiology of man, animals, and plants.
- Evidence of environmental stress such as tranquilizer consumption and social behavior.
- Aesthetic.

Major determinants of the quality of the environment—in addition to the objective parameters and interactions—include perception of the environment by its inhabitants, perception of specific environments or habitats by others, and especially the perception of his own identity by each habitant.

The words *aspiration, arrogance, expectation, jealousy, cooperation, conflict, anomia,* and *frustration* describe ways man senses his environment and his part in it. Perception of the environment by any individual, his estimate of himself, the opinion of others—all are important to the individual's estimate of the quality of the environment. To fully appreciate the importance of these factors, I commend to your reading an article in a recent issue of *Agricultural Science Review* by Sarah Shoffner of the University of North Carolina at Greensboro: "Self Concept: Its Role in Breaking the Poverty Cycle (*9*)." According to Shoffner, recent research has given new credence and validation to the old maxim: "To enlarge what a man can do, you must first enlarge what he *thinks* he can do."

What is good environment? Eric Hoffer relates that he bought a copy of Montaigne's essays, a thousand pages, second hand for a dollar, in anticipation of being snowbound for a winter in the Sierras. He was. He read the book three times. That, he implies is how he learned to write—in a good environment (*3*).

I like the way Hoffer says things. Consider: "The uniquely human fact that discontent is at the root of the creative process, that the most gifted members of the human species are at their creative best when they cannot have their way, and must compensate for what they miss by realizing and cultivating their capacities and talents."

In this time of discontent, will the environment, the quality of life, provide the challenge required to bring together people of all ages, races, opinions, economic levels, and cultures?

What is the present condition of the environment?

The NAS–NAE Environmental Studies Board report of its Environmental Study Group states: "The quality of our lives is directly related to the quality of our environment and the quality of that environment has deteriorated as our national affluence has increased (*2*).

There is no gainsaying the fact that our air is polluted, and increasingly so, with gaseous and particulate pollutants from burning fossil fuels in automobiles and other transport vehicles, in generation of electricity and household heating. Burning crop wastes, forest wastes, forest fires, trash and garbage, gases and fly ash from factory stacks and refineries add their burden. Odors, too, pollute the air—some from agricultural activities.

Our waters are overburdened with sewage wastes, sediments eroded from roads, construction sites, and poorly managed farm, range, and forest lands. Some nitrogen is leached from farm and forest lands, some pesticide chemicals are carried in runoff water and on sediment into our lakes and streams.

Our land is pocked with abandoned, worked-out surface mines—more than 3 million acres of them. Junk and other solid wastes pollute our landscape. And residues of pesticide chemicals—arsenic, lead, copper, mercury, organo-chlorines and others—pollute our soils. Under and about feedlot areas, nitrogen in excess of any possible usage by growing plants becomes a pollutant to soil, air, plants, and water.

Noise and heat are pollutants growing in importance. As yet they are chiefly of local and urban origin.

Pollution is not a new thing. In many cases, pollution is simply over concentration at particular times and places. Pollution is a function of activity per unit area, of people, animals, industry. It is equally obvious that rapid industralization of agriculture and the concomitant accelerated urbanization have resulted in deterioration of many urban and rural environments. Shifts in traffic patterns, growth in automobile and air traffic have impaired the quality of life.

What is agriculture's contribution to the quality of the environment?

It has become fashionable to cite the detrimental contributions of agriculture to the quality of the environment. Although this aspect deserves serious discussion and analysis, we tend to overlook the beneficial contributions—both actual and potential.

It is only because agriculture is efficient that we may hope to improve the quality of the environment, the quality of life. Consider our land resources, for example. We have more than 600 million acres of Class I—III land. Less than half of this is used for crops. Yet our wise use of this land, coupled with improved technology, has made us the leading agricultural nation in the world. The rest of this available land is used for trees and grass and living space; some, unfortunately, goes under pavement every year.

From the viewpoint of potential contributions to the quality of the environment, consider, for example, the opportunities that exist for land planning to provide continuing open space near our cities. Of equal importance is the opportunity for planning the new communities which will be needed for the 100 million additional citizens who will be here in year 2000.

New cultural centers, locations for new industry, new service centers, new recreational centers can be planned to serve both local communities, the States, and the Nation. In addition to assuring land requirements for production of food, fiber, and forest products, we will continue to need coordinated programs for land and urban and industrial development, transportation, outdoor recreation, flood prevention, water harvest, wildlife habitat, and natural beauty.

In my discussion of the undesirable contributions of agriculture to environmental quality, I shall incorporate essential concepts which I think may provide some of the answers we have been seeking. The

key to implementing these concepts lies in the effective use of systems. In agriculture, a system can mean many things.

Every farmer is an ecologist of sorts. He manages an ecosystem, an agro-ecosystem, or several of them. As Kellogg and Orvedal (*5*) have succinctly put it: "Each farmer makes his own arable soil from either a natural soil or an old arable soil. He may change it only a little or he may change it drastically by reshaping the surface for water control, by adding fertilizers to correct plant nutrient deficiencies, by adding other materials to correct acidity or alkalinity or to improve the structure of the soil, or by tilling in depth."

The soil is a living system. Treated wisely, it may sustain man and his living associates, plant and animal, generation after generation, with steadily improving productive capacity.

We commonly think of agriculture in terms of types of farming—dairy, fruit, cash grain, cotton, and so on. Our thinking seems to have been focussed on commodities, not systems. But the systems are there. We have been busy building large scale, highly mechanized commodity production systems without sufficient regard for the agro-ecosystems in which commodities are produced.

Consider cotton, for example. The cotton agro-ecosystem is dominated by a rather uniform population of a single species.

Highest cotton yields are obtained in sunny, long season, irrigated areas. They require abundant, well-managed water, suitable soil, adequate fertilization, good genetic stocks, timely tillage, and pest control. Included in the cotton ecosystem are weeds, trash, trees, ditches, ditch banks, roads, fence rows, turn rows, farmsteads, and frequently, intermingled areas of other crops and woodlands and wastelands. The area included must be large enough so that the more significant populations can complete their life cycles within it. There is likely to be substantial movement of species into, within, and out of the system.

But when we concentrate our attention on a commodity production system—without proper regard for the cotton agro-ecosystem—undesirable things may happen.

In the San Joaquin, for instance, early pesticide treatment for lygus bugs may be followed by explosive bollworm infestations. But planting alfalfa strips and delaying lygus bug treatments permit parasites to help keep lygus bug populations in check without bollworm explosion.

In the Lower Rio Grande, bollworms and the tobacco budworm have developed resistance to pesticide chemicals. Omission of early season chemical pesticide treatment in 1969 was followed by yield increases of 20 percent. Pesticide application was halved.

These practices may be regarded as necessary components of an effective cotton agro-ecosystem. We commonly refer to the whole system as integrated control. The kinds of integrated systems will vary from area to area, depending upon the kinds of pests present.

Ray Smith and his colleagues (*11*) at the University of California have developed concepts and practices for integrated control of cotton insects.

For a number of reasons, scientists are seeking to improve integrated control methods for cotton pests: (1) Cotton is heavily dependent on insecticides, (2) cotton insect pests require a variety of chemicals for their control, and (3) chemicals effective against one insect pest may kill the parasites and predators of another pest against which it is not effective. It seems certain, therefore, that integrated control will continue to play a dominant part in the whole cotton agro-ecosystem.

Another of our commodity production systems—hog production—has also introduced factors detrimental to environmental quality. When the emphasis is on mass production of this particular commodity, waste disposal can seriously disrupt the agro-ecosystem.

The old McLean County hog system minimized the waste disposal problem. Farrowing houses were distributed over the pasture area. The pasture was part of the system; so was the manure; and so were the worms the pigs recycled. Very often, when pigs reached feeder size, they were placed in the cattle feedlot to glean their food from the cattle droppings.

Now we have confinement systems, feeder pig systems, pathogen-free systems. The trend is toward larger and larger units, continuous production, concentrations of large amounts of waste.

One of our most urgent needs is effective waste disposal systems which do not contaminate air, soil, and water. Lagoon systems, even when they work, discharge nutrient-laden effluent into streams.

TABLE 1.—*Waste disposal problem for U.S. livestock raised in large-scale operations in terms of human waste equivalent*

The amount of animal waste produced by—	Is equivalent to the human waste produced by—
5 million feedlot cattle	50 million people
7 million milk cows	105 " "
100 million laying hens	10 " "
50 million turkeys	5 " "
400 million broilers	20 " "
10 million hogs	10 " "
2 million lambs on feed	1 " "
Total equivalent	201 million people

Table 1 shows the massive problem in disposing of animal wastes produced by livestock raised in large-scale confinement operations where wastes are not naturally dispersed. Figures in column 1, which are conservatively estimated, do not include livestock raised in small-scale feeding operations, nor those dispersed on farms and ranges. Note that the total amount of waste produced by large-scale livestock operations is approximately equal to that produced by the entire population of the United States (etsimated at 204 million in January 1970). By 1980, I estimate that the quantity of animal wastes subject to mass disposal methods will be double what it is today.

A number of solutions have been proposed for meeting this massive disposal problem: (1) Composting and ultimate return to the soil, (2) settling, flocculation, dehydrahation, or other means of concentration coupled with ultimate return to the soil, (3) recycling, perhaps selectively, with or without processing as animal feed, (4) incinerating, and (5) *laissez faire;* that is, a do-nothing policy.

All of these methods have defects. In many cases, the cost of waste disposal will exceed the value of the waste to the user. These costs may be reflected in the price of the product or in taxes.

Systems with which we are concerned include the energy system; one burgeoning component of it is electricity. The Office of Science and Technology estimates that 255 new plants will be needed by 1990. They will have a capacity of one million megawatts—three times the capacity of the 3,000 plants now existing. It is probable that 160 plants will have cooling towers by 1990.

Thermal pollution will become a major issue. Location of new plants and burial of transmission lines are already environmental issues. Economic and social costs and benefits will be debated throughout the land. This will inevitably be one of the major environmental issues in rural as well as in urban America and in the world (*8*).

The Unesco Chronicle for November 1969 quotes Moscow University Professors Kalinin and Bykov as follows: "Power is now generated and consumed by industry at such an accelerating rate that this will seriously affect the earth's heat budget. If power generated increased annually by ten percent, in 100 years it will have an effect comparable to that of solar radiation."

What is being done to improve the quality of the environment?

Insofar as public responsibilities are concerned, the several Federal agencies involved in this area have been committing sizeable resources—both human and monetary—to the cause (Table 2). Obviously, we have not committed enough. In an effort to match the projected needs with the vast scope of the problems, a joint USDA-State Task Force reviewed current research programs, needs, and opportunities in 1968. Aside from the very large

continuing research effort on pest control, the Task Force identified a total of about 660 scientist-man-years (SMY's) devoted to research on other forms of pollution in 1966 (Table 3). They projected a need for 1,336 SMY's in 1977—more than double the 1966 effort (*4*).

The Task Force clearly saw the need for systems analysis in solving pollution problems. It also noted

TABLE 2.—*Estimated expenditures on agricultural pollution in 1969*

Pollutant	USDA			DOD		DHEW		USDI	
	R. & D.	Action	Loan	R. & D.	Action Loan	R. & D.	Action Loan	R. & D.	Action Loan
	Million dollars			*Million dollars*		*Million dollars*		*Million dollars*	
Sediment	4.0	289.3	7.0	0.2	186.8			1.3	51.6
Animal waste	1.5	0.8				0.5		0.4	0.7
Processing wastes	1.8	0.9	2.0			0.5		0.3	12.0
Plant nutrients	1.6	1.2				0.1	0.1	2.6	2.4
Forest and crop residues	1.4	24.3	0.1						0.3
Inorganic salts and minerals	1.2	1.6	14.0					1.7	
Pesticides in the environment	45.9	15.0				7.5	2.5	1.9	1.9
Air pollution related to agriculture	1.4	10.0				3.6	2.0		
TOTAL	58.8	343.1	23.1	0.2	186.8	12.2	4.6	8.2	67.9

USDA: U.S. Dept. of Agriculture.
DOD: Dept. of Defense.
DHEW: Dept. of Health, Education, and Welfare.
DI: Dept. of Interior.
Source: See Literature cited (*10*).

TABLE 3.—*Pollution research in the U.S. Dept. of Agriculture, State agricultural experiment stations, and cooperating forestry schools*

Pollution or subject area	1966	1977
	Scientist-man-years	
Animal and domestic wastes	27	140
Processing wastes	30	133
Infectious agents, toxins, and allergens	197	270
Sediment	96	254
Plant nutrients	200	275
Mineral and other inorganic substances	44	95
Radioactive wastes	0	10
Airborne chemicals and particulates	41	114
Noise	1	7
Socioeconomic aspects	2	32
Systems analysis	2	6
Total	640	1,336

a deficiency which still limits the application of systems analysis—a monitoring network such as that proposed under the International Biological Program, a global network of environmental monitoring and local monitoring to guide the systems analysis of local problems.

The report quotes Biniek and Taylor (*1*): "When the general problem of waste management and environmental quality is viewed in total, it becomes obvious that solutions to one resource pollution problem may intensify other resource problems. Transfers of pollution problems to other subject matter areas, or legal or bureaucratic jurisdictions are not solutions in any relevant sense."

What kind of environment do we want?

Dreams of utopia founder for lack of definition and agreement. It is simple to identify an environmental defect; sensory perception takes care of that. But it is difficult—probably impossible—to describe an environment all people would consider ideal.

Criteria and standards for important environmental parameters, such as for air and water quality, are useful and feasible. But may not focussing on such specifics divert us from considering the quality of the aggregate environment of which each of us is a part?

Data on the ratio of green open space to that covered by buildings and pavement are useful. But again this is a reductionist approach to the environment and it can be misleading. Green open space can be a helpful sink for carbon dioxide for other products of industry. But in the city, green plants may be made hideous by pollutants.

Josh Lederberg, in his January 24 column in the *Washington Post* quotes Karl Popper (*7*) who wrote: "Social life is so complicated that few men, or none at all, could judge a blueprint for social engineering on a grand scale . . . accordingly, adopt the method of searching for and fighting against, the greatest and most urgent evils of society, rather than searching for, its greater ultimate good."

Lederberg goes on: "Today we have just one reason to voice an exception; [from Popper's argument] the survival of the human community on earth may be utopian ideal.

"For its realization, we have little experience, tools, training, or organization. We lack even the will to proceed with the long range global planning to meet the realities of today's poverty and tomorrow's revolution of hunger and unfulfilled expectations."

This is indeed a sobering indictment.

But let us look at our proven competence, at our way of doing things. With all Americans, perhaps

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with all people, I am proud that "we," the people of the United States, her scientists, engineers, politicians, and especially her astronauts fulfilled the commitment made by President Kennedy that we would land a man on the moon before 1970.

Between now and the year 2000, over 100 million children will be born in the United States. The way they grow up—and how—will, more than any one thing, measure the quality of American life in these years ahead.

We have a goal, a goal for each of us. Goals and roles. We in agriculture have played and must continue to play an essential role with respect to the quality of the environment and therefore the quality of life. In its role of supplier of food, fiber, and forest products, agriculture in the United States is technology-dependent. Land and labor have become junior partners—a reversal of traditional relations and a reversal which must take place in all the world.

President Nixon said, "The argument is increasingly heard that a fundamental contradiction has arisen between economic growth and the quality of life, so that to have one, we must forsake the other.

"The answer is not to abandon growth but to redirect it."

Elvis Starr, President of the National Audubon Society, put it another way in his speech to the San Francisco Conference of the U.S. National Commission for UNESCO. He said: "The value choices must be made first, and then the technologists and engineers brought into play, in support of these choices. Technologists and engineers are people, too, and as people they have responsibility for sharing in those value choices."

Of course, we've been making value choices and achieving them in agriculture since that art began. We planted in order to harvest. We cared for brood stock in order to harvest the offspring. We managed forest and range in order to achieve sustained yield. Our record of goal achievement—and overachievement—is remarkable.

But now—in the face of the environmental crisis confronting us—our value choices demand more caution, more refinement than ever before. As we attempt to resolve the problems of pollution, the systems we choose must not only be technologically effective but also both socially and economically acceptable.

That is our assignment. No one will likely escape being involved in it.

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UREASE: ITS SIGNIFICANCE IN BIRDS AND MAMMALS

W. J. VISEK

ALL animals live in close association with micro-organisms and maintain a constant defense against invasion of their tissues. What is frequently not appreciated is that metabolic processes of micro-organisms continually produce substances which have important effects upon the host, even though there is no apparent disease or tissue invasion. According to modern authorities, Pasteur was the first to question whether the well-being of animals could be maintained in the absence of micro-organisms, and suggested that the idea be tested experimentally. More recently, pioneering research by groups like the Lobund Laboratory at the University of Notre Dame has established that birds and mammals can grow at normal rates and reproduce in the absence of micro-organisms (*36*).[1]

Warm blooded species acquire a microbial flora a few hours after birth. It is estimated that from 50 to 200 different species of micro-organisms normally inhabit the digestive tract of man. Dead bacteria and their products make up more than one-third of the dry matter of the fresh stool of man (*35, 36*). Gastrointestinal micro-flora can perform beneficial functions, a fact well demonstrated in ruminants. In these animals, microbes of the rumen use dietary constituents of low nutritive value to synthesize vitamins and amino acids and degrade complex carbohydrates to biologically useful compounds. All of these products are then available to the host animal for production of highly important foods such as meat and milk.

During the past decade our laboratory has investigated the production of toxins primarily by bacteria in the alimentary tract. Bacteria produce enzymes which function within the bacterial cells or following their release into the bowel. These enzymes decompose substances that are consumed in

[1] Italic numbers in parentheses refer to Literature Cited, p. 21.

the diet or synthesized by the host. Our work has provided evidence that breakdown products of urea play a significant role in the rate of growth of poultry, swine and ruminants. Because these products also alter cell lifespan and metabolism, they may play a role in aging and cancer. Inhibition of their production by immunization increases survival in irradiated animals. Evidence leading to investigation of these relationships was derived from studies of the way antibacterial agents, fed in large quantities in agricultural practice, promote growth. Confirmatory evidence was obtained with enzyme immunity.

Enzymes, the highly specific catalysts responsible for the majority of biologic reactions, are antigenic proteins.[2] Their injection into a foreign species causes formation of specific antibodies, also called antienzymes. Antienzymes cross-react with the enzymes responsible for their formation or with those which are closely related. An advantage they offer in research over a majority of other antibodies is that their reactions may be followed with three indices: disappearance of substrate, production of products, or the precipitin reaction between enzyme and antibody.

Antienzymes share high specificity with enzymes and are useful for detecting, inhibiting, and characterizing enzymes in multicomponent systems. These properties have proven valuable for investigating enzyme formation, characterizing genetically altered enzymes, detecting alteration of protein structure, localizing enzymes and isoenzymes, and studying chemical embryology. Antienzymes in genetic research have made it possible to relate mutational events to specific regions of the structural gene. Interestingly, the first antienzyme obtained in highly purified form was produced following injection of jackbean urease, which was the first enzyme crystallized. These significant contributions were made by J. B. Sumner of Cornell University, who was awarded the Nobel Prize in 1946. During the past decade we have used this enzyme to study the influence of urea hydrolysis on nine warm blooded species including man. The experimental results have implications in biology, particularly in agriculture and medicine.

[2] Urease is an enzyme that accelerates the hydrolysis of urea into ammonia and carbon dioxide.

Urea Hydrolysis and Release of Ammonia in the Bowel

ALTHOUGH there is uncertainty about the intermediate products of urea hydrolysis, a major product is ammonia. Ammonia is also produced by the normal metabolic processes in cells of all phyla. It is produced by the kidney for maintenance of acid-base balance, and by digestive processes in the gastrointestinal tract. The major sources outside of the tissues themselves are microbes, mainly bacteria, in the bowel. Ammonia arises from actions of microbial deaminases and deamidases and from autolysis of the microbes themselves. A major source in mammals is urea hyrdolysis due to ureases which according to present knowledge are only of plant or microbial origin (*10*).

Ammonia in mammals is converted by the liver to non-toxic urea. Whether endogenously produced by the liver, fed in the diet, or injected—urea distributes rapidly and so uniformly that it has been used as an index of tissue water. About 25 percent of the urea excreted in the urine daily is hydrolyzed in the bowel to its ultimate products, ammonia and CO_2 (*41*). Ammonia so released is absorbed for resynthesis into urea by the liver. The processes for removal of ammonia from blood are exceedingly efficient as evidenced by the very low concentrations in blood after one passage through a normal liver. Some ammonia in mammals and a major part in birds is converted to uric acid, also freely diffusible. Likewise, uric acid enters the lumen of the bowel where it is hydrolyzed by bacterial enzymes to urea and other products, thereby indirectly acting as a substrate for urease (*28*). Normal microbial inhabitants of the bowel produce urease in quantities adequate to hydrolyze all of the urea that is provided to them through normal body processes.

Hydrolysis of urea is virtually abolished or substantially reduced by immunization against urease (*31, 37*). The antibodies responsible for this inhibition enter the bowel in the saliva, intestinal juices and other secretions and inhibit ureases that are free of cells or bound to cell walls. Urease activity is readily demonstrated in cell free extracts of intestinal contents from conventional animals. Such activity is probably released primarily by dying bacteria. Thus, urea hydrolysis is carried on by ureases not subject to control by bacterial cells of their

origin. This uncontrolled release of ammonia and possibly other products such as carbamates (*5*) raises important questions about this lifelong process in which normal body metabolites are degraded as a consequence of the symbiotic relationship between host and bacteria.

The Antibiotic Growth Effect

ORGANIC arsenicals, sulfonamides, and antibiotics represent the "magic bullets" of the famous German bacteriologist, Paul Ehrlich. Their discoveries were the culmination of man's intensive effort to discover substances that could rid the body of infection without harming the host. These drugs have been responsible for enormous changes in medical practice. The finding that antibacterial agents in diets of birds and mammals at concentrations far below the usual therapeutic range would increase growth rate and efficiency of feed utilization in food-producing animals has been described as a hit by the "magic bullet" of an unseen target. Their unexpected effects upon growth were first observed in experiments to study other phenomena. Investigations carried out by Stokstad and coworkers in 1950 confirmed that antibiotics themselves would increase growth in chicks reared under conditions of rigid sanitary and dietary control (*29*). Shortly thereafter, others confirmed these findings in other species (*15*).

The scientific information on feed use of antimicrobial agents in diets of animals is voluminous, and its practical application has reduced costs of food production. Many theories have been proposed to explain the stimulation of growth. At the time our laboratory became engaged in research of this problem, studies with germ-free animals and inactivated antibacterial agents had established that the accelerated growth was due to an action on the intestinal microflora. However, no mode of action had been proposed which was consistent with most of the experimental evidence. The most frequently mentioned theories were:

1. Micro-organisms responsible for clinical infections too mild to be recognized are suppressed.
2. Production of growth-depressing toxins by micro-organisms is depressed.
3. Synthesis of vitamins is increased in those parts of the gastrointestinal tract where the microbial vitamin is made available to the host or when destruction of essential nutrients is inhibited.
4. The wall of the intestinal tract becomes thinner, thereby increasing the efficiency of absorption and utilization of nutrients.

Although several factors might operate simultaneously with differences partly determined by animal species, experimental methods were not sufficiently specific to evaluate their importance (*15*).

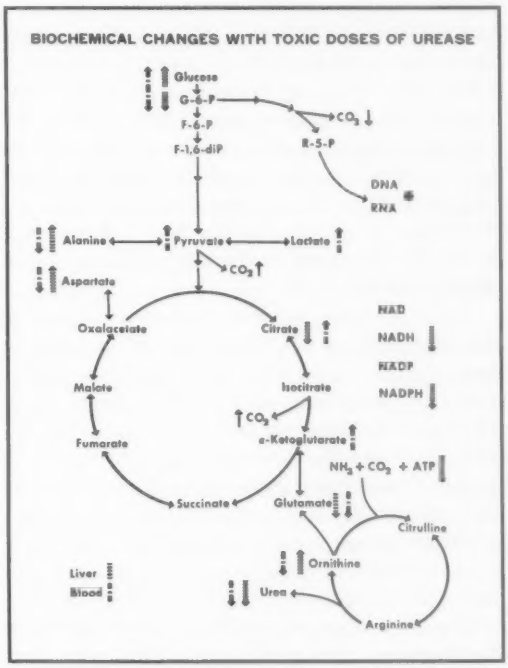

FIGURE 1.—Injections of crystalline urease in toxic dosage cause significant changes in intermediary metabolism. Arrows indicate significant increases or decreases in metabolites for liver and blood. The ratio of oxidized pyridine nucleotides (NAD, (nicotinamide adenine dinucleotide) and NADPH (nicotinamide adenine dinucleotide p phosphate)) to their reduced forms (NADH and NADPH) in liver mitochondria is increased but their total is decreased. The increased ratio is due to a rise in oxidized forms and a disproportionate fall in reduced forms. The pentose phosphate shunt schematically indicated provides R–5–P and requires pyridine nucleotides. This pathway is the only source of 5 carbon sugars for RNA and DNA synthesis* which may be increased or decreased depending upon urease dosage.

Our Investigations

OUR research on urea hydrolysis received impetus from French scientists who reported that nutritional concentrations of antibiotics inhibited bacterial production in the bowel of a growth-depressing toxin which they believed to be ammonia (*12, 22*). We were also well aware of the common practice of treating ammonia intoxication in human liver insufficiency by withholding dietary protein and altering the intestinal microflora with antibiotics to suppress ammonia production (*32, 37*). Our experiments published in 1959 showed that feeding arsanilic acid, penicillin, or chlortetracycline at a concentration of 100 ppm in the diet of rats significantly decreased the metabolism of C–14 labelled urea. The alimentary tracts of the supplemented animals contained less urease activity than the unsupplemented controls. Urease activity was not altered by adding the agents to intestinal homogenates from unsupplemented animals, indicating that lower urease activity was due to a reduction in urease production by the microflora and not to direct inhibition (*38*).

While previous workers established that oral administration of antibiotics and sulfonamides in large dosages would virtually eliminate the gastrointestinal microflora and thereby inhibit urea hydrolysis, the results of our experiments were significant because the concentrations of antimicrobial agents approximated those used in feeds for growth stimulation. More importantly, all three agents inhibited an enzyme for which there is only one known natural substrate, urea. This common action had not been reported previously for these three antibacterial agents fed under identical conditions. Furthermore, this concentration had not been reported to produce consistently demonstrable quantitative or qualitative changes in the intestinal microflora (*15*).

The acquisition of additional information that urea hydrolysis and, in turn, ammonia production had any causal relationship to growth stimulation, to other aspects of nutrition, or to treatment of disease called for a highly specific approach. The technique would have to reliably locate and inhibit a specific enzyme in the complex environment of the intestine without imposing conditions that are unrealistic to the living animal. Existing knowledge pointed to enzyme immunity as a possible approach. At the time there was limited evidence that antibodies would enter the bowel but it was unknown whether a sufficient quantity of antienzymes would enter and be able to inhibit bacterial enzymes. Furthermore, the enzyme used as antigen had to be pure. A mixture of antigens would prevent determination of the factor responsible for any effects observed. We used jackbean urease which could be obtained in crystalline form.

After months of careful evaluation, we established that our enzyme preparations contained one immunologic component (*40*). Our first experiments demonstrated the effectiveness of the chosen approach. About three years later immunologists published evidence describing the mode of transport used by antibodies from blood into various secretions such as those of the bowel (*33*). To date it has not been feasible to obtain pure bacterial urease in the quantity necessary for animal growth experiments.

Rats in our initial experiments were immunized by injections of urease while fed a soybean diet marginal in protein content and free of urease activity. Following immunization, sera from immunized groups contained high concentrations of antiurease whereas no antiurease activity was detected in sera from control animals. Feces and urine of immunized animals also contained urease antibodies. The immunized groups metabolized significantly less C–14 urea and had less urease activity in their gastrointestinal contents. These immunized rats and, in subsequent studies, immunized chicks grew faster and utilized their feed more efficiently than the nonimmunized controls (*8*). Thus the observed changes with respect to urea hydrolysis and growth were like those seen with the feeding of antibacterial substances. Since no urease was fed in the diet, the results were attributed to less microbial urease activity. The lowering of urease activity in the bowel contents by urease immunity was later confirmed in swine by Michigan investigators (*17*).

Subsequently, Tillman and his students at Oklahoma State University found that microbial hydrolysis of urea and release of ammonia could be inhibited in the alimentary tract of sheep fed purified diets containing urea as the only source of nitrogen. Immunization increased growth by 21 percent, and at the same time feed conversion improved. This was a critical test of the capacity of physiological

processes of immunity when properly stimulated to inhibit urea hydrolysis. What may be of equal importance is that urea hydrolysis was decreased significantly in the small and large intestines but not in the rumen (*27*).

These immunity experiments provide evidence that urea hydrolysis occurring in the small and large intestine of all species has significance, and the evidence offers a basis for seeking urease inhibiting agents. By using urease preparations in the test tube it is possible to determine in a matter of minutes if an agent has urease inhibiting activity before feeding it to animals. Seven dietary supplements we studied did reduce urease activity or ammonia in the gastrointestinal tract. All produced an increase in the rate of growth in animals.

Arsanilic acid, chlortetracycline, penicillin and isoniazid have antimicrobial activity. Copper sulfate, used extensively in animal feeds in Europe, is an inhibitor of sulfhydryl enzymes including urease and may exert antimicrobial action when fed. Barbituric acid which does not have sleep producing properties is a urease inhibitor with little antibacterial activity. When fed to chicks, enhanced growth rates were observed (*1*). The seventh supplement, an ion exchange resin developed for the medical profession to remove ammonia from the bowel, significantly increased growth rates in rats when fed at 4 percent of the diet (*13*). Feeding chicks diets containing starch instead of sucrose has also produced more rapid rates of gain in our experiments. Assays of the intestinal contents have shown lower urease activity when starch rather than sucrose was fed (*1*). Lowered urease activity in ruminants has also been observed by others when starch is the carbohydrate.

All of the above eight mentioned experimental approaches, in addition to urease immunity, increased the rate of growth while reducing the concentration of ammonia in the bowel or the potential for its production.

Urease Immunity in Liver Insufficiency

LIVER insufficiency is a common, severe disease in man. Ammonia is detrimental to patients with liver disease, and elevated blood ammonia concentrations cause significant changes in brain chemistry which frequently lead to coma. It is known that the quantity of urea hydrolyzed in the bowel may be sufficient to produce coma. Hydrolysis of urea sufficient to produce intoxication may occur when blood urea is elevated as may happen with impaired kidney function. Patients with liver disease benefit from dietary protein restriction and alteration of the bacterial flora by orally administered antibiotics. Both of these measures reduce ammonia production in the bowel.

Our extensive investigations using urease immunity in several species of animals indicated that man could be immunized with crystalline jackbean urease without harm. To date, urease immunity has been used in 28 patients with far advanced liver insufficiency (*30*). Although it has been impossible to carefully control some of the necessary conditions, accurate hospital dietary records on six individuals show that they were able to increase their protein intake from 80 to 300 percent after immunization (*32*). Immunized patients have demonstrated a reduction in episodes of ammonia intoxication. This reduction has been achieved without antibiotic therapy or dietary protein restriction. Subjects have tolerated controlled dosages of enzyme at 4 to 6 week intervals for 2 years. Some have been immunized for more than 5 years without evident harm (*30*).

Urea balance studies have demonstrated that 94 to 98 percent of intravenously administered labeled urea can be recovered after immunization as contrasted to 65 to 75 percent before immunization (*31*). Recoveries of this order are possible in normal human subjects only with large dosages of antibiotics. These data for man also illustrate the efficiency of immunization as a means of controlling urea hydrolysis. Immunization has not given evidence of causing undesirable side effects which may arise from large intakes of antibiotics. Furthermore, adequate intakes of dietary protein have been permitted on a long term basis, and these are essential for maintaining adequate nutrition.

Urea Hydrolysis and Cellular Renewal

OUR attempts to find the reasons for accelerated growth in animals in which urea hydrolysis and ammonia production were suppressed called attention to well known differences in intestinal histology between germ-free animals, conventional animals, and conventional animals fed antibiotics (*13*). Some of the differences between germ-free and conventional animals are summarized in Table 1.

TABLE 1.—*Characteristics of the small intestine in germ-free and conventional animals expressed as a percentage of germ-free animals*

Characteristics	Germfree	Conventional
	Percent	*Percent*
Weight	100	120–140
Water content	100	110
Mucosal surface	100	130–140
Mucosal cell renewal	100	130–140
Mucosal cell life	100	60–70
Passive transfer of sugar	100	50
Portal blood ammonia	100	400
Phagocytic cells	100	30
Bile acid hydrolysis	None	Yes
Urea hydrolysis	None	[1] 25

[1] Percent of daily excretion.

The mass of intestinal tissues and the mucosal or absorptive surface is 20 to 40 percent greater in conventional animals than in germ-free animals. Not only are there more mucosal cells in conventional animals, but they are replaced 30 to 40 percent more rapidly as evidenced by the normal process of replacement and extrusion into the bowel lumen where they are digested. Functionally, the germ-free intestine permits more rapid transfer of simple sugars. Blood in the portal vein which carries the products of absorption from the bowel contains four times as much ammonia in conventional animals as in germ-free animals. This is due mainly to urea hydrolysis. Bile acids are not broken down in germ-free animals and therefore are reabsorbed as secreted.

Any of these indices studied thus far in antibiotic fed animals fall between those for conventional and germ-free animals. These anatomical and biochemical differences require that the animal maintain a greater mass of tissue and secretions in equilibrium with a more rapid rate of destruction and renewal if bacterial activity is not controlled. Bile acids and plasma proteins are examples of secretions where the rate of synthesis is determined largely by the rate of destruction. On this basis, conventional animals should have a higher basal metabolic rate than germ-free animals; that condition has been found experimentally but not in all cases.

Quantitative data of the influence of microorganisms upon a particular tissue are quite limited. However, some comparisons have been made upon the small intestinal mucosa of germ-free, conventional, and antibiotic fed animals. The mucosa or lining of the small intestine is the most rapidly regenerating tissue in the body. Its rate of regeneration or renewal declines with age, but the rapid rate relative to other tissues appears to be maintained through life (*19*). LeBlond (*18*) has calculated that a 100g rat living in a conventional environment will form 1g of cells each day or 1 percent of its body weight, just to repair its small intestine. The data indicate that 250g would be a reasonable estimate of the cells required daily for intestinal repair in man.

There appears to be no quantitative estimate for intestinal repair in other species, although the time required for complete replacement of the lining of the small intestine in conventional animals has been estimated at 48 hours for chickens, 36 to 48 hours in rats, 60 hours in cats and 40 to 44 hours in man. If a 100g rat gains 5g in body weight each day and synthesizes an additional gram of cells to repair his small intestinal mucosa, he is synthesizing at least 20 percent more tissue than will appear as an

increase in body weight. If the quantity of cells required to maintain the mucosa is reduced 0.4g by removal or control of bacteria (Table 1), some of the nutrients so spared should be available for increased growth. If this diversion is assumed to be quantitative, body weight gain would be enhanced 8 percent which is approximately the increase observed with antibiotic feeding. On the same basis, a 1000g broiler gaining 50g daily might synthesize 10g of cells to maintain the small intestine. This also represents 20 percent additional tissue. If 4g or 40 percent were diverted to other tissue of equal weight, there would also be an overall body weight increase of 8 percent.

If we extrapolate LeBlond's data from a 70kg man to a hypothetical 700kg cow, 2500g of cells would be formed in the small intestine daily. Conversion of this quantity of cells on a protein equivalent basis would equal 14kg of milk or about 30 lbs. On first consideration, the extrapolated values seem outlandish and may be very inaccurate. However, they concern only the small intestine and not other tissues where cell renewal takes place. Regardless of the validity of these extrapolations, we were encouraged to seek methods of determining if urea hydrolysis or ammonia played a role in cell death and renewal.

It is worth repeating that cells and plasma proteins which enter the gastrointestinal lumen must first be synthesized before they are redigested and reabsorbed. Their constituents are largely reused but represent a substantial increase in absorptive and synthetic load. Furthermore, any tissue such as the intestinal mucosa that is carrying on rapid synthesis of new cells requires a readily available supply of all nutrients for cell synthesis. If such vital tissue is deprived of nutrients, the economy of the whole animal can be adversely affected. This would be characteristic of a wide variety of circumstances where antibacterial agents lead to more frequent and greater increases in growth. Antibacterial agents have been shown to increase growth on diets limited in energy, protein, fat, water soluble vitamins, fat soluble vitamins, or minerals (*35*).

It appears that cellular and tissue renewal resulting from the influence of micro-organisms on cell function, replacement, and life span could serve as a basis for theories frequently proposed for the growth-stimulating actions of antibacterial substances. For example, diarrhea which is reduced with antibiotics might be due to irritants produced by bacteria without tissue invasion by pathogens. Irritative agents such as ammonia or deconjugated bile acids could also facilitate entry of infectious agents as has been seen with viruses (*2*). Feeding of urea in our own studies has caused alterations in tissue histology in localized areas of the intestine which were prevented by feeding of 100 ppm of dietary chlortetracycline (*35*).

Evidence That Urea Hydrolysis or Ammonia Causes Cell Death

EVIDENCE that hydrolysis of urea destroys cells was obtained in immunity experiments with rabbits receiving a single weekly intravenous injection of crystalline jackbean urease (20 μg/kg body weight) for 4 weeks (Table 2). While the blood of control

TABLE 2.—*Hematological changes caused by injection of crystalline jackbean urease in rabbits* [1]

Type of treatment	White blood cells $10^3/mm^3$	Hematocrit Vol. (Percent)	Hemoglobin g/100 ml blood
Saline-injected rabbits	9.0±1.5	35.6±0.2	11.5±0.1
Urease-injected rabbits	5.3±0.2	31.1±0.1	10.3±0.1

[1] Rabbits were given a single intravenous injection of crystalline jackbean urease at weekly intervals for 4 weeks. Each injection contained 2 units (20 μg) of urease/kg body weight. Blood was taken immediately prior to and at 5, 24, and 48 hours after injection each week on all animals. Values are averages plus or minus standard errors.

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rabbits receiving sodium chloride solution had an average of 9.0 thousand white cells/mm^3, 35.6% packed red cells and 11.5 gm of hemoglobin/100 ml, respective values for urease-injected rabbits were 5.3, 31.1 and 10.3. Rabbits injected with urease showed a sharp rise in blood ammonia which remained elevated for at least 8 hours. Concommitantly, there was a fall in blood urea which remained severely depressed for 8 to 24 hours. However, as the rabbits became immunized, changes in ammonia, urea, and the formed elements of blood following each urease injection were smaller (*9*). Similar depressions in white blood count, hematocrit, and hemoglobin followed injections of ammonium salts, but repeated dosages were required. Single injections of ammonium salts failed to elevate blood ammonia for more than an hour in animals that lived and had normal liver function.

Evidence That Urea Hydrolysis Alters DNA Synthesis

DNA (deoxyribonucleic acid) is the hereditary material in cells which determines the chemical and physical properties of living organisms. Chromosomes contain high concentrations of DNA which is responsible for the transfer of genetic information. Every normal resting cell of a given tissue contains a quantity in its nucleus which is characteristic of the species. Radioactive thymidine, a specific precursor for DNA, is valuable for assessing DNA synthesis, cell lifespan, and cell regeneration.

Rat thymus slices incubated *in vitro* with small concentrations of urea and urease showed increased thymidine incorporation into DNA. With greater quantities of urea hydrolyzed, thymidine incorporation into DNA was inhibited. When mice were injected with 0.05 to 0.15 units of urease thymidine, incorporated into DNA of spleen was enhanced; whereas in liver, testes, ileum, and colon there was no difference between saline and urease-injected mice. At 15 hours after 0.4 unit of urease was injected, thymidine incorporation was increased in liver and spleen and decreased in the ileum and colon (Table 3). Whether there was a decrease or an increase at 15 hours, all tissues tended to return to control values with increasing time after injection (*43*). Determinations of total DNA, protein and other indices agreed with these results (*43*). Our autoradiographic studies, which are another experimental approach, also demonstrate that ammonia changes labeled thymidine incorporation into DNA (*44*).

Protection Against Irradiation

IMMUNIZATION of animals against ureases significantly depresses or virtually eliminates *in vivo* hydrolysis of endogenously produced urea. It is logical, therefore, to question the relevance of this fact and the data on cell lifespan and DNA synthesis to a real life situation in the whole animal. Some answers to this question were obtained by using whole body irradiation. Lethal dosages of ir-

TABLE 3.—*Incorporation of labeled thymidine into DNA of tissues in mice after urease injection*

Tissue	Hours after last injection of urease			
	15	27	51	99
	Radioactivity/Mg DNA as percent of control mice			
Testes [1]	122	100	99	81
Liver	204	128	142	121
Spleen	143	140	95	101
Small intestine	69	66	88	96
Large intestine	44	58	94	103

[1] There were no changes in organ weight or body weight. Two injections of urease (0.4 unit) were given at 12-hour intervals followed by thymidine 12 hours later.

radiation destroy cells and inhibit new cell formation particularly in rapidly regenerating cell populations like those of bone marrow or intestinal mucosa. Inhibiting urea hydrolysis, a process which also kills cells, should increase resistance to irradiation damage.

Repeated experiments with several hundred mice provided evidence that immunizing mice with antiurease from other immunized animals gave significant protection against lethal dosages of whole body irradiation. The median lethal dose at 30 days for untreated animals was 600 rads as compared to 860 rads for mice given urease antisera. Exposure to 800 rads resulted in the survival after 30 days of 21 percent of the control animals whereas over 70 percent survived if given immune antisera from rabbits before irradiation. Normal nonimmune sera gave no protection (Table 4). Survival was greater with known radioprotective chemicals such as S·beta-amino-ethyl isothiouronium Br·HBr (AET) and β-mercaptoethylamine HCl (MEA) than with urease antisera.

Similar results have been obtained in our more recent experiments with mice exposed to X-rays and treated with antisera from the horse. All of this evidence points to urea hydrolysis as a factor to be considered in irradiation sickness, a disease in which bacteria play a significant role and cellular kinetics are severely disturbed. These results with urease immunity and those showing increased survival in irradiated animals following diversion of intestinal secretions emphasize the detrimental effects from the presence of intestinal secretions and bacteria in the irradiated animal (*39*).

Urease activity is highest in the colon of nonimmune animals. When H^3-thymidine is injected into such animals following urease immunization, incorporation into DNA of the large intestine has been reduced 20 percent in our preliminary experiments.[3] These unpublished data indicate that microbial hydrolysis of urea with production of ammonia increases cell synthesis in the lining of the large intestine. In accord is the finding that cell damage is greatly enhanced in kidneys infected by urease producing strains of Proteus bacteria in contrast with their non-urease-producing mutants (*20*). Others have also reported that ammonia may alter processes of cell renewal in cultures of chick fibroblasts, mammary gland slices, or in kidneys of living animals (*4, 26, 34*).

Biochemical Changes Due to Urea Hydrolysis

ALTHOUGH many questions of a biochemical nature remain to be answered, evidence derived to date is in accord with our observations relating urea

[3] Zimber, A. and Visek, W. J. Unpublished data.

TABLE 4.—*Survival of white mice 30 days after exposure to 800 rads of CO^{60} whole body irradiation*

Treatment [1]	No. of experiments	Ratio	Percent surviving
0.9 percent sodium chloride	6	20/75	26
Normal non-immune serum [2]	4	2/40	5
Urease-antiserum [3]	6	54/71	76
AET [4]	5	53/57	94
AET plus antiserum	5	51/54	94
MEA [4]	2	19/26	73
MEA plus antiserum	2	21/22	95

[1] All treatments were administered by injection before irradiation.

[2] Blood serum obtained from normal non-immunized rabbits.

[3] Serum obtained from rats immunized against jackbean urease.

[4] AET—S beta-aminoethyl isothiouronium Br·HBr; and MEA—β mercaptoethylamine HCl (both known radioprotective agents).

hydrolysis to growth of animals, cell lifespan, DNA synthesis, cell regeneration and irradiation sickness. Our laboratory has been able to obtain data on biochemical changes which occur during acute intoxication by utilizing the ability of injected jackbean urease to severely elevate tissue fluid ammonia.

Ammonia intoxication following injection of ammonium salts has been extensively studied in other laboratories because of its importance in brain metabolism and liver disease in man. Since ammonia is rapidly detoxified in animals with normal liver function, constant infusion of ammonium salts is required to sustain elevated blood ammonia levels. Such infusions produce changes in body fluid pH which alters thymidine incorporation into DNA and other processes (*4*). On the other hand injection of crystalline jackbean urease or oral administration of urea can produce intoxication or death while plasma pH, pO_2 and pCO_2 remain within physiological limits for periods which permit sequential measurements. In addition, these treatments more nearly simulate the natural process of urea hydrolysis. This approach has the additional advantage of providing intermediate products of urea hydrolysis in the sequence which they are formed in the body, a fact of considerable importance if the intermediate products also produce biological effects.

Injections of urease produce a sharp rise in blood ammonia which persists for 8 to 12 hours. Blood urea declines sharply to extremely low concentrations for 8 to 24 hours. By regulating the oral dose of urea, blood ammonia may be elevated for desired periods. As ammonia is produced from urea, detoxification mechanisms in the body are stimulated. Strategic aberrations in biochemical pathways then become evident (fig. 1).

The starting point for our biochemical experiments during acute intoxication was provided by Japanese scientists who found that ammonia added to liver mitochondria *in vitro* depleted the reduced pyridine nucleotides (*6*). In our laboratory, mitochondria from rats injected with toxic dosages of urease showed an elevation of the oxidized pyridine nucleotides (NAD and NADP) accompanied by a non-stoichiometric decline in the reduced forms (NADH and NADPH). This change in the two forms of pyridine nucleotides and a decrease in their combined quantity agreed with the findings of our Japanese colleagues. These workers also reported that ammonia added to mitochondria from normal animals activated an oxidase enzyme which destroyed the reduced forms. We found this enzyme to be activated in mitochondria isolated from intoxicated animals. This finding suggests that ammonia increases the requirements for dietary niacin and tryptophan which are essential for pyridine nucleotide synthesis.

Other important metabolic changes are also indicated. The pyridine nucleotides are indispensible cofactors in intermediary metabolism. They are necessary for the pentose-phosphate shunt which is the only source of five carbon sugars for DNA synthesis. NADPH participates in maintaining red blood cell populations which we found to be reduced in urease-injected rabbits and urea-fed sheep (*24*). The pyridine nucleotides also play a role in glycolysis, the TCA cycle, and ATP formation. ATP is used in reactions requiring metabolic energy and is essential for maintaining the urea cycle.

Of considerable value has been the finding that data obtained in acutely intoxicated rats are predictive of changes to be expected when other species are acutely intoxicated or fed urea in their diet. For instance, the finding that blood glucose, pyruvate, and αketoglutarate were consistently elevated in rats prompted us to follow these indices in other species (*7*) where blood volume is sufficient to permit time course measurements. Thus far, biochemical studies with whole animals or with tissues from intoxicated animals verify that intermediary energy metabolism is severely deranged, and that DNA synthesis can be increased or decreased depending upon the quantity of urea which is hydrolyzed.

It is well known that ruminants intoxicated with a lethal quantity of ammonia may be successfully treated with vinegar or acetic acid. Such animals show sharp decreases in blood and ruminal ammonia (*43*). However, free plasma amino acid patterns are also profoundly altered when the animals are comatose or at the peak of their toxicity. Within less than an hour after administration of acetic acid, intoxicated animals will rise to their feet and frequently ingest feed. Before ruminants are fully recovered, their plasma amino acid patterns have returned toward normal—indicating that intermediary metabolism of amino acids

is also deranged by the intoxication (7). Such intoxication experiments have provided leads to the design of feeding experiments with urea in ruminants. These experiments are beginning to show that the feed value of urea may be increased beyond present expectations by supplementing the diet with nutrients which maintain specific processes in cycles of intermediary metabolism. They also are pointing out species differences in these pathways which offer avenues for progress.

Conclusion

THE fact that immunization with urease inhibited urea hydrolysis *in vivo* while growth rate was increased added significance to our observation that certain growth promoting agents inhibit urease directly or decrease its synthesis by bacteria. Immunization confirmed the participation of urea hydrolysis in the so-called antibiotic growth effect. Immunization and urease injections also showed that urea hydrolysis causes cell death, alters cell renewal, and increases the number of deaths due to irradiation sickness. Since antibacterial agents are non-specific in their actions on micro-organisms, they may alter other microbial processes which contribute to increased growth of the host. The results with urease immunity establish the effectiveness of

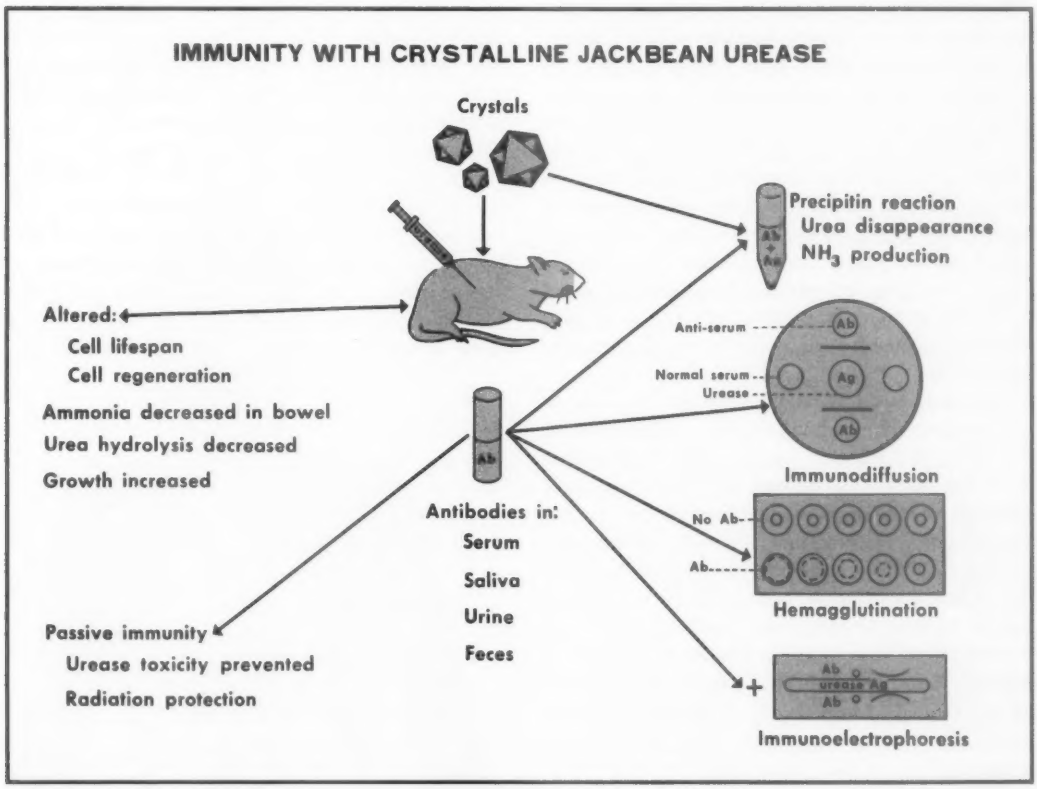


FIGURE 2.—Animals injected with immunizing dosages of urease produce antibodies (Ab), detectable in blood serum, other tissue fluids and excreta. The antibodies react with antigen (Ag) which may be jackbean urease or urease from other sources. These antibodies can be quantitated and characterized by precipitin reactions, hemagglutination, immunodiffusion and immunoelectrophoresis. Human type-O red blood cells coated with urease provide a highly sensitive means for detecting antiurease by hemagglutination. Immunoelectrophoresis makes it possible to fractionate fluids by means of electrical current and to determine the antibody-containing component. Passive immunity may be conferred upon non-immuned animals by injection of serum from immunized animals.

the immunological approach for studying these and other processes in the bowel which are due to antigenically active substances (fig. 2). For example, bile acid hydrolysis like urea hydrolysis is carried on by bacterial enzymes which are free of the cells that produce them (*23*). When products of bacterial hydrolysis of bile acids are added to diets of animals, growth is inhibited, intestinal histology is altered, and other abnormalities are produced. According to the evidence with urease immunity, it is clear that bile acid hydrolysis may be studied by immunological methods if appropriate antigens are used. Once such antigens are available they can be used to study their effects on body chemistry and other phenomena as shown with urease.

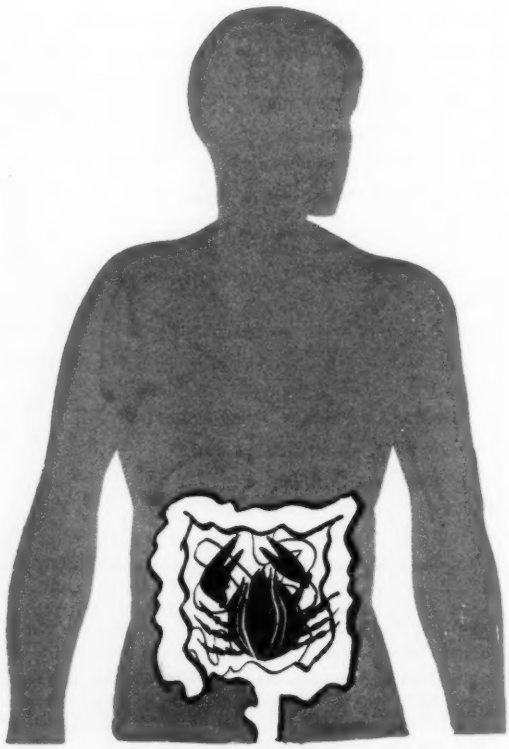
Urease immunity as a growth promotant has been studied under laboratory conditions and has not been shown to improve diets that give high performance. A major disadvantage of urease immunity is the need for repeated immunologic challenge if antibody activity is to be maintained at the required levels. However, slow release depot preparations containing urease and other antigens appear feasible and might be prepared so that a single injection would suffice. Immunization has some distinct advantages. Its specificity permits control of the selected process by normal body secretions with minimum potential for alteration of bacterial populations.

In contrast to antibacterial agents or other chemicals, urease immunization has the specificity needed to control the selected process with dosages that avoid side effects to the host and other nontarget processes. Furthermore most antigens are readily destroyed by processing methods and antibodies are proteins which are consumed normally. Thus residues which frequently contaminate meat or products of animals treated with chemical agents are avoided. Even if immunization fails as a practical measure, it offers an effective means for establishing the biological importance of molecular species which can then be studied for alternate methods of control.

Lifespan and regeneration of cell populations has great importance. The bodies of man and lower animals continually form new cells to replace those that have outlived their usefulness. The fact that urea hydrolysis alters the lifespan and production of cells as shown by studies on blood, nucleic acid synthesis, and survival of irradiated animals demonstrates that bacteria produce products from normal body secretions which require animals to maintain a greater metabolic and synthetic load. This alteration diverts nutrients from production of useful products, a hypothesis which has excellent support from studies which were discussed. The fact that cells are destroyed, however, means that the products of urea hydrolysis may hasten processes of aging. Destruction of cells is particularly significant in tissues like the brain where certain cells cannot be replaced.

Another important consideration is that production of new cells in some populations such as spleen, bone marrow, testes, or intestine can be increased. This increases the number of cells susceptible to malignant change.

The fact that the degree of urease activity in our studies and those of Dintzis and Hastings (1953) in simple-stomached species tends to parallel the inci-



dence of cancer in the alimentary tract of man is circumstantial evidence that urea hydrolysis may be a factor in cancer initiation or promotion (*11, 16*). Cancer of the digestive tract in man accounts for the largest number of newly diagnosed cancers each year in both sexes. According to Bailer, *et al*: "Cancer is a group of diseases found in all ages and races of man and in all other species. Since 1937 it has been the most frequent cause of death in man in the United States" (*3*).

The digestive tract is the area of the body in which urea hydrolysis occurs at the highest rate. Urea hydrolysis obviously does not cause a large number of cancers in a short time. However, it is a lifelong process that yields one and possibly three products known to have profound effects on cells. Carbamates are produced under some conditions by urease activity (*5*). Carbamates are converted by microsomal enzymes to hydroxylamine. Even though these compounds are undoubtedly produced in small quantities and have a very short existence carbamates are carcinogenic and hydroxylamine is mutagenic. Ammonia, the major product, increases cell proliferation. There is evidence that proliferating cells have increased susceptibility to carcinogens (*25*). Ammonia has already been suggested as having a role in carcinogenesis (*42*) and increasing the incidence of viral infection (*3*). Viruses are recognized for a role in carcinogenesis in some species.

Ammonia in gaseous and ionic form has been reported in the atmosphere over urban areas at concentrations of ammonium ion equal to 60–70 percent of the total cations. It has been calculated that the urine of domestic animals in the United Kingdom contains urea equivalent to 750,000 tons of ammonia per year (*21*). Ammonia transported by air currents from feedlots has been shown to contaminate nearby lakes (*13*). Urea used in feeds in the United States in 1968 totaled 230,000 tons and urea manufactured for fertilizers was more than 2,300,000 tons. These usages are increasing each year. In order to make the nitrogen available to plants and animals, urea must be hydrolyzed by ureases. Urea hydrolysis, therefore, is essential or the environment will be overburdened with urea. Urea, being a normal metabolite of man and lower animals, cannot be escaped or banned by legislative action as is true of other chemicals. The evidence that urea hydrolysis and release of ammonia have harmful consequences demonstrates need for greater understanding of the process if it is to be controlled for maximum benefit. The fact that man and all lower animals have evolved in a symbiotic relationship with micro-organisms which facilitates urea hydrolysis as a normal process seems insufficient reason to ignore examination of the questions which it poses.

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QUALITY OF LIFE—(*Cont. from inside cover*)

life rather than *quantity of production* the criterion of their success. It has become apparent that progress only means moving forward, but not necessarily toward a desirable goal. The widespread awareness that we may have to change our course will generate entirely new kinds of social and scientific problems.

The phenonmenal increase in agricultural, as well as industrial, productivity has been due in large part to the much greater use of power, especially from fossil fuels, and of natural resources, especially in the form of mineral fertilizers. Until now, the development of new techniques has been focused on more economical utilization of such power and resources. But this approach is no longer sufficient, because shortages are in sight with regard to supplies of both power and resources, also because wasteful and careless utilization is generating the many manifestations of the ecological crisis.

All ecological systems, whether natural or man-made must eventually achieve a state of equilibrium and be self-regenerating with regard to both energy and materials. The ecology of all modern prosperous nations has been in a state of disequilibrium for several decades, and this is particularly true for the United States. Furthermore, ecological instability is increasing at such an accelerated rate that we cannot delay much longer the development of a nearly "closed" system in which energy is produced within the system instead of being obtained entirely from the outside, and materials retain their value through recycling instead of being discarded as pollutants.

The ecological constraints on agricultural production will inevitably lead to economic and technological structures very different from the ones under which we operate today. Many persons will be alarmed at this prospect and will fear that the world is about to enter a period of stagnation leading eventually to decadence. But life within a closed system is compatible in fact with an immense variety of qualitative changes; it will indeed offer intellectual challenges much more interesting than those associated with the kind of rampant, careless, and wasteful growth that prevails at present. But this will require a new kind of scientific research.

In my opinion, the nearly "closed" system that I anticipate will soon compel a reorientation of the agricultural enterprise, in its theoretical as well as practical aspects. Such reorientation cannot be successful without creative effort on the part of the academic scientists and their willingness to refocus their efforts on the problems of the contemporary world. The readjustment will often be painful; but its reward will be the prospect of a happier society and of a scientific renaissance.

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CONSUMER BEHAVIOR OF YOUNG ADULTS

ROBERT O. HERRMANN

EACH generation is shaped by its own unique experiences and, in a fast-changing world, the experiences of one generation and the next may differ greatly. These differences in generational experiences are illustrated dramatically when we compare the experiences of the young adults in the 18 to 24 age group now reaching marriageable age with those of their parents. Because of the differences in what they have experienced in the course of their lives, it is not surprising that both the attitudes and the

behavior of the two generations differ. One aspect of behavior which seems especially likely to differ between the two generations is their behavior as consumers.

Three major forces have played a role in shaping the consumer behavior of the new generation of young adults: (1) the experience of growing up in a period of almost unbroken prosperity, (2) permissive techniques of child-rearing and (3) a high level of education and heavy exposure to the mass media.

In the interests of unity, this review focuses on only one segment of the young adult group—those from middle income families—which probably constitute 70 to 80 percent of this age group. Excluded from this review, therefore, are two other groups of substantial interest and concern: youth from low-income families and the dissident radical fringe, many of whom are from upper-middle class families.

Behavior-Shaping Forces

THE experience of growing up in a period of almost unbroken prosperity has had a broad and pervasive influence on the economic attitudes of the new generation. Since World War II, most families of child-rearing age found themselves better off each year, or at least as well off. These improvements in financial well-being among families with children produced a widely shared feeling of optimism about future increases in incomes and levels of living (15).[1] The optimism of the parents of the 1950's and 1960's probably was heightened by comparisons of their situation with what they had experienced as young people in the 1930's. In 1966, the purchasing power of typical families with children was about two and a half times greater than it had been 25 years earlier (*34, 37*). The optimistic economic expectations of the new generation should be of little surprise when we consider the atmosphere in the families in which they grew up.

The second major force influencing the new generation has been the permissive technique of child-rearing, with its emphasis on greater tolerance for the child's impulses and desires, freer expression of affection, and psychological methods of discipline rather than physical punishment. The shift of middle-class families away from the more rigid disciplinary styles of the 1920's and 1930's to more permissive techniques of child-rearing has been documented by Bronfenbrenner. There also is evidence that working-class families have adopted both middle-class values and psychological techniques of discipline with the result that the differences which formerly existed between middle-class and working-class child-rearing practices have narrowed (*4*).

These permissive techniques have been found to have an important effect on children's behavior and have been linked by researchers to a reduced capacity for initiative and independence, especially in boys. After surveying research in this area, Bronfenbrenner concluded that "males exposed to this 'modern' pattern of child-rearing might be expected to differ from their counterparts of a quarter century ago in being somewhat more conforming and anxious, less enterprising and self-sufficient, and, in general, possessing more of the virtues and liabilities commonly associated with the feminine character structure" (*5*).

The third major force which has influenced the behavior of the new generation is their higher level of education and heavy exposure to the mass media. The new generation has completed considerably more years of education than its parents did (*37*). There is, in addition, reason to believe that the quality of a "year" of education has improved considerably in the past 25 years. Standards of performance certainly are higher, school years are somewhat longer, and attendance is better (*37*).

The new generation has been heavily involved with the mass media from an early age. It is the first television generation and, as children, they spent an average of 20 to 21 hours per week in television viewing (*39*). After vacations and weekends are taken into account, this is roughly as much time as was spent in class at school. Viewing typically began early; more than one-third of all children were regular viewers at age 3, and by kindergarten 80 percent were regular viewers. Much of this viewing has been of shows usually considered to be "adult" (*31*).

The new generation also has been heavily exposed to print media with advertising content. Most began reading the newspaper on a daily basis in about

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[1] Italic numbers in parentheses refer to Literature Cited, p. 30.

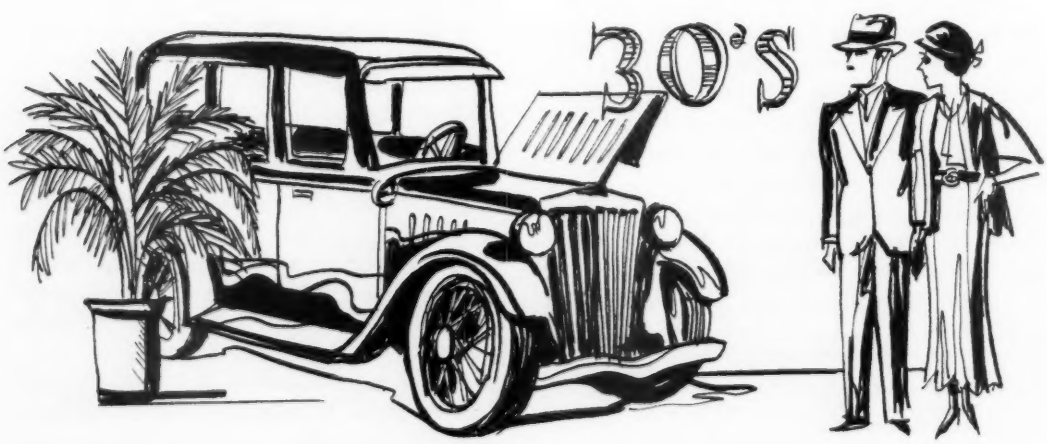
grade 7 or 8 (*30*). Their reading programs have also included a wide variety of magazines. Younger teenagers read magazines especially aimed at their age group, like *Boy's Life* and the *Scholastic* magazines, and the mass circulation magazines like *TV Guide, Life, Look* and *Reader's Digest,* as well. Older teenagers have been observed to have reading patterns much like adults. The boys read the mass circulation magazines and special interest magazines like *Hot Rod* and *Sports Illustrated.* One media survey estimated that 39 percent of all girls age 14 to 17 read a typical issue of *Seventeen.* They also read the mass circulation magazines and, anticipating their future roles as wives and mothers, read the women's and home magazines (*10*).

Consumer Behavior

THE foregoing three sets of unique generational experiences appear to have had a significant influence on the behavior and attitudes of the new generation. They are, first off, highly optimistic about their future financial situations and level of living. This attitude, undoubtedly, is due to the air of satisfaction and optimism which prevailed in their families as they grew up. Their optimism also may be a result of the new knowledge, which has become widespread, that incomes typically rise with age, and that this rise is most marked for those with more education (*15*). As a result of their youthful experiences, this new knowledge, and, perhaps some youthful enthusiasm, young adults have been found to be the most optimistic of all age groups about future increases in income and level of living (*18*).

Almost all young people look forward to what Riesman and Roseborough have labeled the "standard package"—the set of durable goods, clothing, food products and services enjoyed by the majority of Americans (*28*). Cateora's study of teenagers in a Texas high school provides some details on the exact nature of these expectations. He found that the teenagers which he studied expected their first home to have things which probably had taken their parents years to acquire. Seventy-six percent expected their first home after marriage to have air-conditioning, 79 percent expected a washer, 45 percent expected a dryer, and 38 percent expected to have a dishwasher. Although the expectations of youth from working-class families were more modest than those of the youth from middle-class homes, they were, nevertheless optimistic (*6*).

Another result of economic prosperity has been that the new generation grew up with substantial amounts of money which they were free to spend much as they pleased. They may not, however, have learned much in the process that will be relevant to the management of their financial affairs as adults. The amounts available to youth for their own spending have increased greatly since the 1930's



and 1940's. Gilbert, the market researcher who pioneered in investigating the youth market, estimated that the spending money (including both allowances and earnings) of high school boys and girls increased four-fold between 1945 and 1959—from $2.50 to $10 per week (*11*). Most of the new generation, except for some youth from poor and rural families, received an allowance or other money from their parents which they were free to spend with little parental supervision (*9, 24, 25, 29*). Except for some farm youth from low-income families, most of the new generation also had significant amounts from their own earnings (*9, 13, 24, 29*).

The available research suggests that their experiences with money have provided the new generation with little useful buymanship information or money management experience. Although handbooks on child-rearing typically recommend allowances as a device for training children to manage money, there is little evidence that allowances or the opportunity to earn money at home actually do improve children's financial knowledge and responsibility (*20, 21, 26*). Moreover, the very nature of children's and adolescent's spending limits its usefulness as a training device. Children's and teenager's purchases are largely for discretionary items like toys, entertainment, small clothing items and snacks. Since their families provide the basic necessities, they are under little compulsion to manage their money carefully and are free to spend as they please. While these discretionary purchases may provide some training in the selection of merchandise, they seem unlikely to provide much motivation for learning to budget and manage money carefully.

Cateora found that while most teenagers recognized that one should shop around for the best price on a desired item, most admitted that they would buy in the first store which had the item they wanted. Most also admitted that once they had made their choice, they tended to insist on the item they preferred, regardless of relative prices (*6*). Even among students in home economics classes, a group whom one would expect to more likely have spending plans, only a limited number were using techniques usually considered to be a part of careful money management. In a nationwide survey by Hurt of 51,968 students in high school home economics classes, only 40 percent were found to have a plan for spending and only 19 percent kept a record of their spending (*13*). Although most surveys indicate that youth "save" part of their income, undue importance probably should not be attached to this fact. Much of this "saving" activity appears to be for small target purchases rather than long-range needs such as education (*7, 24*).

The amount of experience which the new generation has with their own credit accounts as teenagers seems to vary between regions. Special teenage credit accounts seem to be more widely available in the Southeast than in the Northeast (*32*), and seem to have been utilized by a significant proportion of the older teenagers in the South-

east. In their study of 12,317 white teenagers in South Carolina schools, Powell and Gover found that 40 percent of the 12th grade boys and 20 percent of the 12th grade girls had their own charge accounts (*25*).

The new generation seems wary of consumer credit and well aware of the dangers of misusing it. This attitude may be a result of observing the experiences of their own and other families in using credit (*6*). Data from surveys taken over the last 13 years by the University of Michigan Survey Research Center suggest that the young adults of today actually have a somewhat less favorable attitude toward the use of installment credit than did the same age group of 13 years ago (*18, 22*). However, the proportion of young families actually using installment credit has increased. In 1967, 69 percent of the families with heads in the 18 to 24 age group had such debts (*18*). This apparently reflects a feeling that although there are risks in the use of credit, it is all right to use it, as long as it is used sensibly. The increasing number of consumer bankruptcies and the relatively young age of many of the bankrupts (in several studies the median age has been around 30) indicates that there are some casualties among the younger users of credit (*12*). The proportion of young families heavily committed to installment debt payments has however, declined in recent years. Fewer families with heads in the 18 to 24 age group now have an amount in excess of 20 percent of their previous year's disposable income committed to installment debt payments—a level sometimes considered to be a dangerline (*16, 17, 18, 23*).

It appears that the consumer behavior of the new generation also may differ from that of the previous generation because of the increased influence of peers on consumption patterns. The more dependent, conforming child produced by permissive child-rearing practices is sensitive to the opinions of both his parents and his peers. Although parents of the new generation exercised a great deal of influence on basic values and such crucial decisions as the career choices of their children, they seem to have exercised less influence on their consumption behavior (*3, 8, 27*). Generally, they have left their children free to gambol in what Douvan and Adelson have called "the consumption fairyland." The strong influence of peers on consumption patterns and styles which has been observed among teenagers seems likely to continue into adulthood.

As a result of their long and heavy exposure to the mass media and their better educations, the new generation has developed a skeptical and questioning attitude toward product claims and advertising. This attitude seems to be part of a general increase in skepticism among youth. This increase in skepticism is reflected in the changes over the years in the responses given by high school students to the question: "Do you feel that you can believe what you read in the newspapers?" When students were asked this question in 1949 by the Purdue Opinion Panel (*33*), 41 percent said "yes." Thirty-nine percent replied affirmatively in 1959, and 33 percent in 1964. Business claims also may suffer from the generally skeptical attitude of the new generation toward business. The problems which business has experienced in recruiting new college graduates has become a familiar story in recent years.

The popularity of *Mad* magazine in recent years not only reflects the skeptical attitude of youth, but also has fed this skepticism. *Mad*'s satirical treatment of modern life and customs has received wide circulation among teenagers. Advertising has been a frequent subject for parody, as have, to a lesser extent, business customs. Both these subjects were found by Winick to be favorites with *Mad* readers. *Mad*'s focus on the incongruences between espoused social standards and actual behavior was found to have special appeal to those teenagers who (a) were better students, (b) came from higher income families, and (c) were especially sensitive to the problems depicted (*38*).

Despite their skepticism, the new generation does seem to value the advice of accepted experts. They are more familiar than earlier generations with the concept of the "professional" and his role in providing personal assistance. Higher-income youth, in particular, are familiar with such professionals as doctors and have been found to have a more favorable image of physicians than do lower-income youth who probably have had fewer contacts with them (*2*). This attitude toward trusted professionals suggests that advisors on consumer problems should be able to work successfully with young adults, if they are able to establish themselves as trusted experts.

Consumer Education Needs

THE picture we have sketched of the new generation shows them full of optimism about their financial futures, experienced in spending money but lacking any real experience in managing it, inclined toward conformity with peer-approved consumption styles, and skeptical of advertising and product claims. It is a portrait which shows both potential strengths and weaknesses. The dangers of over-optimism, inexperience, and conformity are balanced, at least in part, by a healthy amount of skepticism.

The new generation clearly needs consumer information and education. It is not well prepared for adult money-management roles either on the basis of its past experiences or by training. Because of its skeptical attitude toward product claims and advertising, the new generation will accept, and even seek, expert advice on consumer problems. This advice however, must, be both authoritative and unbiased. The new generation will have little use for so-called consumer advisors who are either poorly informed or seek to promote some special interest. To succeed with the new generation, consumer educators must perform with the expertise and concern for their client's best interests characteristic of true professionals.

The new generation seems especially interested in expert guidance in selecting products. From childhood, they have exchanged a great deal of product information among themselves. Now, as adults, they seem more interested in product testing information than did earlier groups of the same age. During the 1960's the proportion of Consumers Union subscribers under the age of 25 has increased significantly—from 3.0 percent of all CU subscribers in 1960 to 4.8 percent in 1967.[2] Although the under-25 households still are under-represented in CU in relation to their numbers in the total population (*35, 36*), this shift in the composition of CU membership does seem to be a hopeful sign.

In addition to buymanship information, the new generation also badly needs guidance in managing its finances. Their discretionary spending as children and teenagers has provided them with little relevant information or experience in money management. Few ever kept written records or did any long-term saving. Money management information may be of little interest to young singles or newlyweds, who typically experience few money problems. Such information seems more likely to be of interest to young marrieds after the arrival of their first child. It is at this stage when money first becomes a subject of disagreement between husband and wife (*1*), and concern about the family's financial situation is greater than at any other stage in the family life cycle (*19*). This stage may be the teachable moment for financial management information.

The new generation is not well-informed about consumer credit despite the fact that most of them are using it. Data from the 1967 Survey of Consumer Finances suggest that the new generation is no better informed about the cost of credit than the rest of the adult population. Along with the rest of the adult population, they tended to underestimate the cost of automobile installment credit when questioned about a hypothetical borrowing situation. The 18 to 24 age group was, however, more confident of their answers than some of the older age categories questioned; fewer of the younger age categories gave "don't know" answers to the question (*18*). Although the new generation is wary of credit, most do use it. However, consumer educators should be certain that young consumers are not simply giving in to the blandishments of credit retailers who play on their eagerness to get what they want, but are, instead, using credit sensibly to meet their own needs. There are indications from the Survey of Consumer Finances data that the problem of establishing credit is of special concern among young adults (*18*). This topic may be useful as an opening wedge for a more comprehensive program on credit costs and terms for young adults.

The new generation seems likely to be more interested in consumer education and more concerned about consumer problems than previous generations. They seem especially sensitive to and resentful of business attempts to take advantage of the consumer. Their interest in consumer problems seems to be part of a broader concern about the welfare of the powerless in their dealings with the powerful. This concern about the rights of the under-dog apparently has its origins in the equalitarian and democratic emphasis of many parents

[2] Personal communication from Robert L. Smith, Asst. Director, Consumers Union, Feb. 18, 1969.

who employed permissive child-rearing techniques (*14*). It may result in a generation which is both more sensitive to poor and careless treatment by retailers and manufacturers and more favorable to consumer protection legislation.

Conclusions

THE new generation of young adults constitutes a major challenge for consumer educators and researchers. This new generation clearly needs help. The past experiences and education of these young adults provide them little basis for dealing with the rapid changes in both income and financial responsibilities they typically encounter. Available research results, unfortunately, provide only partial coverage of this age group. Most of the available information concerns college students, the one category in this age group which is a captive sample for researchers. As a whole, the group is markedly under-researched compared to younger age groups which are more easily accessible to researchers.

The narrow age span covered and similarities in income may make the young adult age group appear less diverse than it really is. It is, in fact, quite heterogeneous—including college students, those beginning blue-collar careers, young-marrieds, "swinging singles," and more. Moreover, it is an age in which roles and concerns change quickly with employment, marriage, and parenthood. Any useful research must take account of this diversity and its effects on expenditures, goals, and expectations.

Although the young adult age group is heterogeneous, it does share certain common tasks and problems—the problems of adjusting from the role of a dependent child to that of an economically independent, productive adult. The very generality of such problems as adjustment to geographic and occupational changes, the financial management of a newly independent consumption unit, and conflict over inter-generational financial help, makes them worthy of attention.

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A FARMER VIEWS THE ENVIRONMENT

JAMES G. HORSFALL

THE concept that a farmer might offer a few useful solutions to our environmental problems carries a refreshingly different connotation. In this case, the "farmer," while not exactly a man of the soil, has ably demonstrated in many ways his deep understanding of the ecological forces that govern our total environment.

This article was adapted from a talk which Dr. Horsfall made at Boston, Massachusetts to the deans of instruction of New England colleges and universities on April 1, 1970 when they met to discuss proposed environmental curricula. It embodies many of the ideas which he presented at the initial meeting of the Governor's Committee on Environmental Policy [Connecticut] on which he served as chairman.

MOST of the environmental excitement is among city men. It is they who are frightened, because they have suddenly discovered that Nature fights back.

This quality of Nature is hard for the city man to understand, for he had always thought of Nature as being soft and kind. He was accustomed to using the term, "Mother Nature." He prattled about the mystical balance of nature. He always considered this as favorable to man.

But now he sees that Nature will exact her price. He throws smog into the air; Nature flings it back at him. He dumps his wastes into rivers, and Nature refuses to cleanse the waters, as she did back in grandfather's day.

In contrast, the farmer has long been slapped around by Nature. When he mistreated his soil, Nature fought back. She washed it away, and he ended up tilling subsoil.

A city man has probably never seen a cow killed by lightning, nor a field of wheat hammered to the ground by hail, nor a forest set ablaze by skyfire.

But a farmer knows intimately the awesome power that Nature can release.

The city man has suddenly discovered the Tragedy of the Commons.[1]

The farmer has known about this principle for centuries. He calls it carrying capacity. An acre of ground will carry only so many cows; a tree can carry only so many apples. When the carrying capacity becomes overloaded, he eases the burden by thinning out. Actually, this is population control. Sometimes man practices it; sometimes Nature does.

We scientists have done innumerable experiments on carrying capacity—spacing, thinning, plant breeding. This research is invariably aimed at a function the plant performs. We may shorten the plant height by breeding. Thus we can put more individuals on each acre and absorb more energy, especially early in the season. We fertilize it with extra nitrogen so that it will manufacture more nutrients. We discover a gene for better transport so that more sugar can be transported to the ear. We treat a plant seed so that it will be better able to withstand disease organisms in an unfavorable soil environment. By selective breeding we develop a corn ear with tougher husks to discourage flocks of marauding birds. We dispose of wastes by returning straw and manure to the soil.

Need for Reorientation

THUS, the argicultural sciences contain all the basics for establishing courses on the environment. Instructors may, however, have to reorient their thinking. Take research for example.

I think one day farmers will use some of their land as giant compost heaps to recycle city wastes. If so, agronomists will have to rotate 180° on subjects relating to organic matter. Up to now, they have tried to maintain a high degree of organic matter. Now, they must try to get organic content down.

Soil microbiologists, too, will have to rotate 180°. Up to now, they have tried to hurry nitrogen on into nitrate. Now they must try to liberate it as N_2 and complete the cycle to prevent eutrophication.

Likewise, entomologists must reorient their thinking. Up to now, they tried to get maggots out of cow manure. Now they must figure out ways to use those maggots to aid in recycling that waste.

Regardless of whether we are teaching environmental courses in a classroom, or selling a concept to the public, or devising legislative ways to prevent a global "tragedy of the commons," our goal will remain constant: how to live pleasantly enough while reducing the price that Nature will exact of us.

Can this be done?

Realistically, we cannot escape to Walden Pond. Nor would we want to. Instead, we must face the fact that there are certain functions that people on the commons are bound to perform—produce energy, for instance, market goods, dispose of waste, build houses, seek recreation, and so on. These are functions similar to those that a population of corn plants performs on its commons. The real problem is to continue to engage in these activities in such a manner that will result in the least insult to Nature.

It was on this basis that we on the Governor's Committee on Environmental Policy [Connecticut] began our study. We were concerned, of course, with designing a State policy. Perhaps colleges and universities concerned about educational gaps in environment issues could take the same approach in designing curricula.

Let me briefly discuss a few of these functions with you.

Energy Production

ENERGY production is the favorite whipping boy for environmentalists. Yet energy is essential in a modern society. Although no one really likes dams, smoky power plants, atomic reactors, or even that old furnace in the basement, we certainly don't intend to saw lumber by hand, nor bathe in cold water in a cold bathroom.

The question is not which method of producing energy will please the environment. Rather, the question is: Which method insults it least? Hopefully, a comparison of environmental costs of the three sources of electrical power—plus the family furnace and including the flooded valleys, belching stacks, warm shad, and tank farms—will show the best way for obtaining our energy needs while harming the environment least.

[1] See "The Tragedy of the Commons" by Garrett Hardin, *Science* Vol. 162. Dec. 13, 1968. Hardin uses the parable of the commons in colonial Britain. Every villager had the freedom to pasture his cow there. The commons is finite but villagers had an infinite freedom to put cows on that finite commons. Eventually, of course, the commons collapses, especially under a sudden stress such as a drought. New York City's water commons came dangerously near to collapse in the great northeastern drought of 1965.

Marketing of Goods

WHAT are the relative costs to the environment of obtaining our groceries, our drugs, and clothing from the market place? Shall we package these goods in tin, aluminum, plastics, or paper? Which is the least costly to the environment? The litter problem unquestionably must be solved at this stage—the marketing step—rather than later out of reasons of piety.

Waste Disposal

WASTE disposal is a fantastic insult to the environment. In the years ahead, the problem will become even more serious than it is today—not only because of increased amounts but also because of the growing inadequacies of present disposal methods.

We have, I believe, only five alternatives: burning, burying, flushing, hiding, and recycling. Some of these methods merely transfer the problem to another facet of the environment. Even hiding the waste on the "back forty" can adversely affect the landscape both aesthetically and materially. And of course in many cases, the farmer has sold the back forty to a new owner who has other plans for his land.

Those who make the decisions will have to determine, for example, whether collection of all sewage from the suburbs in vast treatment plants is more or less insulting to the environment than dispersing it wherever possible by proper septic tanks into those soils capable of absorbing it.

* * *

Regardless of which function of human activity is being considered, ingenious ways will have to be devised to change the rules and customs so that people will find it profitable and stylish to disturb the environment as little as possible. This is where education enters the picture. So it is commendable that colleges and universities are taking the initiative to teach the citizenry how to live harmoniously with the environment.

We need to remember, however, that not all of our environmental problems can be solved by our present knowledge. We must turn to research to help us find ways of doing things that are now undesirable or even intolerable. But until our present knowledge is expanded by research, surely we can use some of the philosophy that has been developed by dirt farmers and erstwhile farmers like you and me. A farmer knows and loves the soil. He views his environment with respect. This attitude, this philosophy, must be universally adopted, it seems to me, to give us the motivation to use our beautiful environment wisely.

Plaudits and Protests

Prompted by a bit of urging on the part of our Editorial Board, the editorial office of *Agricultural Science Review* has decided to abandon its previous policy of saying nothing about any honors the journal has earned. The string of honors is long enough now, it seems likely, that we can own up to it and at the same time mention the latest one.

On May 13, 1970 *Review* won the second place award for excellence in the 7th annual publications contest of the Federal Editors Association. The coveted Blue Pencil award was given to the editor by Senator Tom McIntyre of New Hampshire at the National Press Club awards luncheon. *Review* had been entered in the category of technical magazines—a grouping in which the competition is consistently brisk.

Our record now stands as follows: one first place award, three second place awards, and being ranked among the top five federal science magazines for six of the seven years the journal has been published. These honors are humbly acknowledged; they are testimonies to the efforts of many people who are involved in this publishing endeavor.

In one way, the action of the contest judges seems to offer supporting evidence that *Review* might be showing signs of achieving its original goal of becoming a viable influence in the scientific community by exciting inquiring minds. Whether this is true or not is, of course, a matter for readers to decide. And the best way to gauge the situation is through reader feedback—thoughtful, provocative letters showing that readers (a) support or oppose authors' ideas, or (b) are motivated to discuss the issues further. We will be happy to consider such letters for publication in *Review*.

WARFARIN-RESISTANT RATS IN BRITAIN

ALTHOUGH the announcement of the presence of warfarin-resistant strains of rats in Britain is not particularly significant as a news item (the first case was documented in 1958), the story of the research effort to cope with the situation is a fascinating example of how scientists are uniquely equipped to solve environmental problems that result partly because of prior technology they had helped to create.

Insofar as the editorial office of Review *has been able to determine, no known agriculturally related cases of such resistance in the United States have as yet been documented.*

THE resistance of man's enemies to the chemical compounds used to control them is a well-known phenomenon. Pathogenic bacteria have become resistant to antibiotics; insect pests of agriculture and disease vectors have become resistant to new synthetic insecticides and, most recently, rodents have become resistant to a group of rodenticides known as the anticoagulants. Warfarin is the most widely used of these compounds which, as their collective name suggests, act by interfering with the clotting ability of the blood. Rats feeding upon bait containing an anticoagulant normally die from internal bleeding within a week to 10 days.

The discovery of the rodenticidal properties of warfarin and allied compounds about 20 years ago heralded a breakthrough in rodent control. Warfarin-type compounds were not only extremely effective and safe in use compared with the older, acute poisons such as arsenic: they were also very cheap and simple to apply. By the middle or late 1950's warfarin had justifiably won a dominant position in the rodenticide market in Britain and throughout the world.

This article was adapted from a paper which was published in *Agriculture*, a journal of the Ministry of Agriculture, Fisheries and Food, Vol. 77, No. 3, March 1970.

Resistance to Warfarin

IT WAS, therefore, a matter for concern when the first case of resistance to warfarin was discovered in 1958 among rats on a farm just outside Glasgow. It soon became evident that the resistance, by the time it had been discovered, had already spread extensively. The inadequacy of the acute poisons, the only alternative rodenticides, now became all too apparent, and it was a practical impossibility to exterminate the resistant population. The area in Scotland now affected by resistance covers upwards of 800 sq. miles.

The second significant report of resistance concerned two farms in Montgomeryshire in 1960. Here, despite the vigilance of local pests officers and health authorities following the Scottish outbreak, the resistance was once more not discovered until it had spread too far to be stamped out, and today resistant rats occur in an area of at least 1,000 sq. miles in Montgomeryshire and Shropshire.

A third outbreak was discovered in 1968 in Kent where resistant rats are now known to have spread through an area of 40–50 sq. miles. These are the only areas where resistant rats are known to have become established in Britain. There have, however, been a number of instances in Somerset, Gloucestershire and Nottinghamshire where outbreaks have been identified at a sufficiently early stage to make eradication of the resistant rats feasible by intensive use of acute poisons. Most recently, rats resistant to warfarin have been found in Berkshire and Carmarthenshire. It is, however, as yet too soon to be sure that the attempted elimination of these outbreaks has been successful.

In continental Europe resistant rats are well established in Denmark, while in Holland a small outbreak early in 1968 appears to have been stamped out. Less well authenticated instances of resistance to warfarin in rodents have been reported elsewhere in the world, for example in the sugar cane fields of Guyana and in the rice paddies of Ceylon. It seems possible that wherever warfarin is intensively used for a substantial period of time, rodent populations may have the capacity to respond by developing resistance.

Research

A SMALL group of biologists in the Ministry of Agriculture, Fisheries and Food's Infestation Control Laboratory engaged in research on harmful mammals has been closely involved in the problem of warfarin-resistance since it first occurred. Their work includes severely practical, on-the-spot investigations of new outbreaks of resistant rats and also more theoretical studies aimed at elucidating the nature of resistance and the variables influencing its spread in rat populations. It is only by exploring a whole complex of biological factors, ranging from the feeding behavior of the rats to their physiology and genetics, that the resistance problem can be adequately understood and laid open to attack.

The recent discovery at the Laboratory of genetical linkage in rats between resistance of the Shrop-

How Serious Is the Rat Problem?

In the absence of detailed surveys, world governments have been able to only guess about their food losses from rats. But the informed guesses are disturbing enough, according to an FAO report.

Even in a country like the United States, with sophisticated ways of protecting what it grows, grain destruction by rats is estimated to be about 5.3 million tons annually. The situation is much worse in many parts of Africa, Asia, and the South Pacific. India estimates that grain losses from rodents run as high as 10.3 million tons annually. FAO officials state that 55 million Africans could each be fed for a year from the grain finding its way to the wrong consumers—the rats, the quelea birds, and similar pests.

The enormity of the food losses caused by rats can be attributed to the same factor that is characteristic of certain other animal species, particularly man—rapidly expanding populations. Rattus natalensis, *the most destructive rat in Africa, produces litters of 10 to 20 once a month from the age of 3 months, and may continue to do so for several years. One pair of Indian bandicoots—rats as big as cats—can multiply to 900 within a single year.*

And so the populations grow. When they are hungry, the storehouse of man becomes a handy pantry.

shire-Montgomeryshire type and coat color is one more step forward, albeit to the layman a rather esoteric one, in understanding the problem. In particular this linkage provides one of the most convincing kinds of evidence showing that the resistance is passed from parent to offspring by means of a single heritable unit or gene. This is important because resistance, if due to a single gene, can spread more rapidly through the rat population than if several different genes are involved. Because the resistance gene has now been genetically mapped with reference to other genes determining coat color, it will also be possible to say more precisely in future whether new instances of resistance are of the same or of a different kind.

Overcoming Resistance

THE main research projects at the Laboratory are, however, linked in a more obvious way to the practical problems of overcoming resistance. One such experiment has been an attempt to isolate the resistant rats in Shropshire and Montgomeryshire. Between 1962 and 1965 surveys indicated that the resistant rat population was expanding across the countryside at the rate of about three miles per year. In 1966 an intensive survey established the limits of resistance, and a zone roughly three miles wide was delineated around the perimeter of the resistance area. All the places likely to harbor rats on this perimeter or containment zone were systematically inspected and every infestation that was discovered, small as well as large, was treated with acute poisons. Every farmer in the containment zone was also asked to call upon a special, free, rat-destruction service being operated by the Ministry whenever rats appeared on his land in future.

It should be emphasized that this containment scheme was a purely experimental project by means of which it was hoped to discover whether, by increasing the efficiency of rat destruction and by imposing the maximum voluntary restraint on the use of anticoagulants in the containment zone, the outward spread of resistance could be halted. Unfortunately, events seem to have conspired to reduce the success of the scheme.

First the epidemic of foot-and-mouth disease that affected the area in 1967 imposed restrictions on the movement of Ministry operators so that for a period of some months they were unable to visit all the farms requiring treatment. Second a considerable number of farmers in the containment zone continued, despite all efforts to persuade them otherwise, to use warfarin. This practice, by selectively eliminating susceptible rats, helped the resistance to become firmly established in the containment zone. Eventually, monitoring operations showed that in 1969 in a further three mile wide zone outside the containment zone a small proportion of the rats were resistant. This proportion, small though it was, showed conclusively that the effort to contain the resistance had not succeeded. It can be predicted that increasing difficulty will be experienced in dealing with rat infestations just outside the containment zone by means of anticoagulants. To the extent that the containment scheme has slowed down the spread of resistance and so gained time for the development of other countermeasures, it has, however, provided a useful breathing space.

One of the more significant features of the situation in the Shropshire-Montgomeryshire resistance area is that, in spite of the fact that about a third of the farmers are continuing to use warfarin-type compounds, the incidence of resistance among the rat population appears to have reached a plateau. It will be obvious that if susceptible rats are being selectively destroyed by warfarin, then the proportion of resistant animals should be increasing. The only possible explanation for such stabilization of the resistance is that the resistant rats suffer some disadvantage relative to the susceptible rats in respect of environmental pressures other than the use of warfarin.

The possible nature of this disadvantage has been revealed by the work of a group of American biochemists studying resistant rats descended from animals sent across the Atlantic from Infestation Control Laboratory some years ago. They have found that the resistant rats require more vitamin K than do susceptible rats to keep them in good health. In the field it is quite likely that the amount of available vitamin K is, at times, insufficient to maintain resistant rats while being quite adequate to sustain susceptible animals. These observations strongly suggest that if anticoagulants could be completely supplanted by other rat poisons in the area affected by resistance, then not only the further spread of resistance might be prevented but also the resistant

rats would dwindle in numbers over the years and perhaps eventually disappear.

Use of Rodenticides

THERE are, unfortunately, many difficulties in the way of any serious attempt to regulate the use of particular rodenticides in this way. While common sense dictates the strategy of using only non-anticoagulant rat poisons, this can prove difficult in practice because the effective alternative poisons are much more dangerous to humans and livestock. There would be a very much greater incentive to users of rodenticides to switch from warfarin if an equally safe and effective alternative were available. Again, the provision of satisfactory alternatives to the anticoagulants would be the best long-term protection that could be offered to people living outside the existing resistance areas and would enable new outbreaks of resistance to be stamped out much more easily than at present. For these reasons the highest priority is given at Infestation Control Laboratory to the search for new compounds suitable for use as rodenticides.

The prospects of success in this project are difficult to evaluate and no one can be sure just how soon or how long it will be before a compound as good as warfarin is discovered. The pharmaceutical, pesticides and chemical industries are playing a major role in the project by providing, for testing, samples of novel compounds synthesized by their teams of chemists. The Laboratory itself has no commercial interest in the compounds and is in effect making special facilities and expertise available to industry. This approach is of mutual advantage because in the pharmaceutical industry, for example, thousands of new compounds are synthesized each year which eventually turn out to be useless to medical science; many such compounds prove too toxic to be used as drugs and it is precisely this sort of compound that is likely to be of greatest interest as a possible rat poison.

Up to the present there has been no obvious increase in rat infestation as a result of resistance in Britain, possibly because the areas that have been affected so far have been predominantly rural. Rats have always been quite numerous in the countryside and though undoubtedly farmers are, on occasion, having problems in dealing with resistant rats, they can, in general, keep infestations down to a fairly low level by the use of acute poisons. If, however, resistant rats were to spread into urban areas—and it is here that, with warfarin, rat control has been as intensive and successful in Britain as anywhere in the world—local authorities would encounter difficulties in maintaining standards by the use of acute poisons. But, provided the necessary resources are allocated to the work, urban rat control need be no less effective than it was before warfarin came into general use. Fortunately, however, it is likely to be some years before this situation arises, and there is a good chance that research will provide an answer to the problem in the meantime.

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FORUM

MEMO TO COLLEGES OF AGRICULTURE

The following "memo" was originally directed to the agricultural colleges of Canada. Is there perhaps some relevancy in this message for U.S. agricultural colleges?

I BELIEVE our modern colleges of agriculture are failing to adjust fully to the fact that the community they serve has changed and is changing. More important perhaps, the problems which perplex it have changed markedly over the years.

It is true that colleges of agriculture have changed in many ways since the first one in Canada, the Ontario Agricultural College, was established nearly a century ago. While the term "cow" college may have been accurately descriptive in the early years, it was not long before the sciences were introduced into the agricultural colleges. Research into the problems of crop and animal production and farm mechanization, carried out largely in colleges of agriculture, provided the technology that has made agriculture one of "the three industries that together . . . with steel and automobiles . . . have powered the tremendous growth of the developed economies of the West (and of Japan) in the last 20 years".[1]

[1] Drucker, Peter F. *The Age of Discontinuity*. Harper and Row, 1968.

These advances in agricultural science and technology have resulted in a success story unparalleled in history. Production per acre has been increased. Production per worker on the farm has been increased dramatically, releasing large numbers of people for more productive work in other industries. The percentage of income required to purchase his food has steadily decreased for each Canadian.

Success Holds Danger

THE danger of success, however, is that it may lead to complacency. The past success of agriculture, and indirectly of colleges of agriculture, in applying science and technology to production is not sufficient justification for the continuing existence of colleges of agriculture.

Within many university agricultural faculties, there is concern about "the image of agriculture". This concern is justified. If one were to ask the officials of any faculty of agriculture what really new programs have been introduced in the last 30 years, they would be hard put to think of one. Yet there are plenty of new problems.

If faculties of agriculture continue to act as traditionalists who react to criticism by pointing out the great accomplishments of the past in increasing food production, and fail to see new and more pressing problems to solve or missions to serve, then colleges of agriculture deserve their image. Certainly, they will not be fulfilling the total role of which they are capable and which this generation has a right to expect of them.

Among the faculties that are found at universities, none have been more oriented toward the problems of people than have colleges of agriculture. But people have problems of interaction with their environment that are not related to food supply, recreation, waste disposal and housing, to name a few.

We need a broader view. The word "agriculture" really means "the science of land" and one definition of the word land is "any ground, soil or earth regarded as a subject of ownership as meadows, pastures, woods and everything annexed to it whether by nature (trees, water) or by man (as buildings, fences) extending indefinitely vertically upwards and downwards." (Webster's Third New International Dictionary).

Many of the problems which perplex society today are related in some way to land, not just for production of food but for recreation, for transportation and communications, for houses, factories, schools and cities. Questions of allocation of land for various purposes and, after allocation, the problems of using it effectively for the planned purpose, and the problems of how to avoid despoiling the land (soil, water, air) by intelligent disposal of the "effluent of our affluent society" are questions of real urgency and relevance.

Broader Outlook Needed

I BELIEVE it is time that colleges of agriculture redefined their mission to make it more broadly relevant to the problems that "perplex society;" problems that will yield to the application of the principles of agricultural science, problems that extend well beyond but include the problems of food production. Colleges of agriculture should be concerned with the total relationship of man to land.

I do not suggest that colleges of agriculture now have people who are capable in each of the several aspects of the problem of man and his environment. They generally lack the necessary strength in the social sciences, especially sociology and politics. While there are some sociologists in colleges of agriculture, there need to be more of them.

Some might argue that sociologists and political scientists in faculties of arts should be encouraged to coordinate with the faculties of agriculture. I am not optimistic about the likelihood of this. We need sociologists who are interested in the problems of man's relationship to animals, plants and land, not just man's relationship to man as has been, and still is, generally the case.

Perhaps the best way to meet the need is to recruit sociologists and political scientists, as has been done with economists, into the college of agriculture. There is a need for a department of human ecology in the college of agriculture. Such a department would include people who are interested in man's relationship to his environment from man's point of view; call them human ecologists if you wish.

If colleges of agriculture do not accept the challenge of these new missions, other colleges will be established to do the job. This would be regrettable, not because the image of the college would be further tarnished, but because the acknowledged scientific strength in the college of agriculture will not be effectively mobilized to attack the pressing problems of human ecology that do not involve food.

Critical internal study of its mission will inevitably involve the college in a study of its internal organization. Most colleges of agriculture are organized on a "commodity" basis, that is, there is a department for field crops, for horticulture, for animals, for poultry, for soils, etc. But the actual problems are not confined to one particular department or a single discipline. They transcend them.

There must be a mechanism for transcending the departments, a means of orienting the whole college in a coordinated approach to the problems. Colleges of agriculture traditionally seem to suffer more than most from "unscalable walls" between departments. The faculty that can manage to batter down these walls will be effective in solving real problems which are invariably "interdisciplinary".

Too often, those of us in colleges of agriculture, when faced with the criticism implied above, take a defensive stance. We should, rather, set out boldly to review our missions and our academic emphasis.

Let us choose as our missions those that we can make distinctively our own. Let us not choose to emphasize or assume special responsibility for missions such as general education in science that can be and often are assumed by other faculties. To do so will only cloud our vision and prevent us from seeing the special missions that should be ours—missions such as the solution of the problems of people in the modern, urbanized rural environment, the proper use of land and other natural resources to meet the competing needs of society, and the pressing problems of maintaining the quality of our natural environment.

I am confident that agricultural colleges have the professional capability and the orientation toward real problems of people that will enable them to play a leading role in these new missions, as well as in the traditional mission of increasing food production. We have the capability. Do we have the foresight to embrace the opportunity?

B. C. Matthews, Vice-President,
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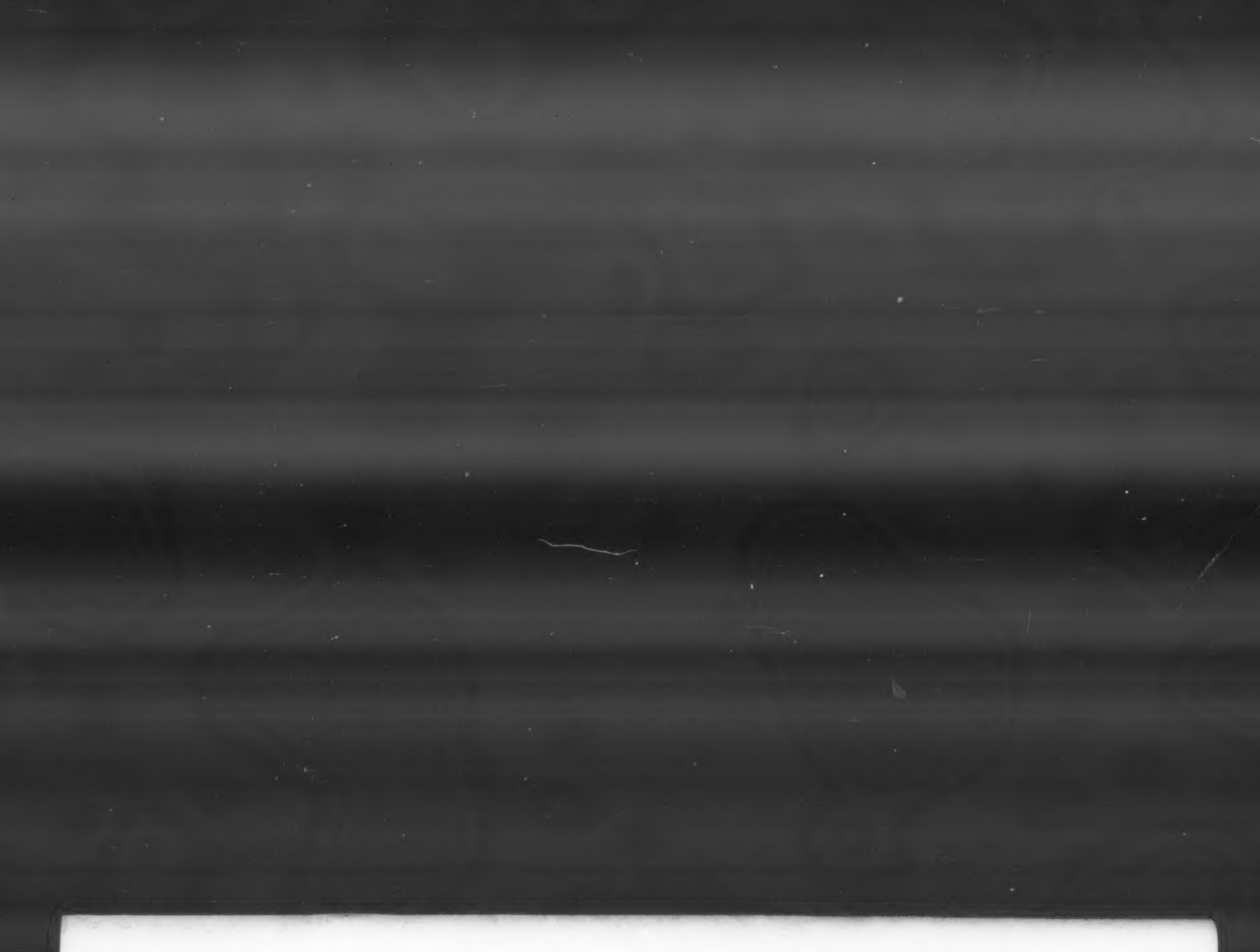
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